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WATER QUALITY AND HYDROGEOLOGY OF TWO SMALL AGRICULTURAL BASINS IN CENTRAL PENNSYLVANIA

SUSQUEHANNA RIVER BASIN COMMISSION

Publication No. 155

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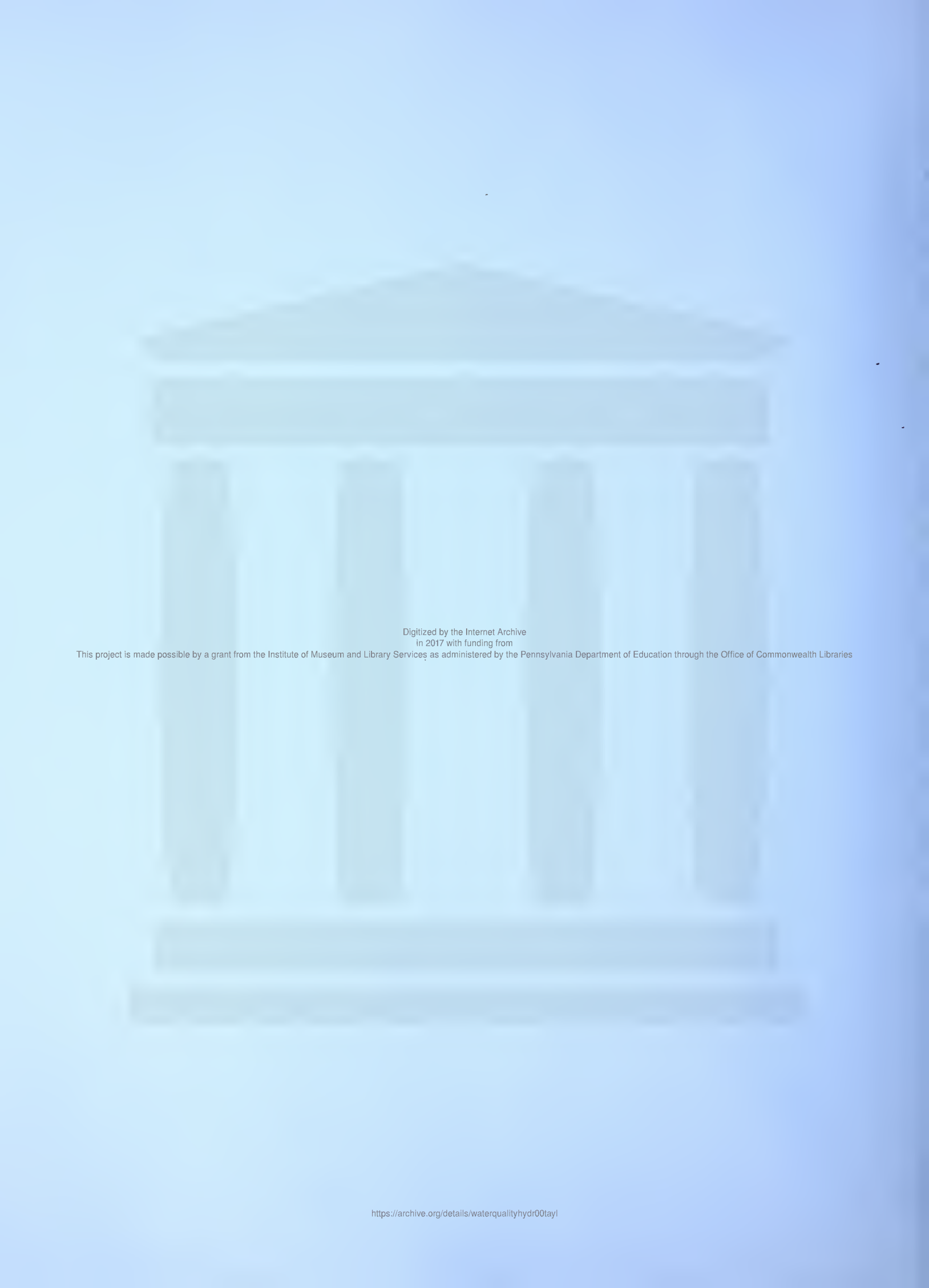

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WATER QUALITY AND HYDROGEOLOGY OF TWO SMALL AGRICULTURAL BASINS IN CENTRAL PENNSYLVANIA

BY

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**Statutory Citations: Federal - Pub. L. 91-575, 84 Stat. 1509 (December 1970); Maryland - Natural Resources Sec. 8-301 (Michie 1974); New York - ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).*

Publication No. 155
March 1994

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ACKNOWLEDGMENTS

Paul Clugston, farmer at Halifax, and Ann and Colonel Tom Darlington, owners of the land farmed by Bill Harmon, have been extremely cooperative and supportive throughout the project. The Pennsylvania Department of Environmental Resources, Bureau of Laboratories, performed all of the water and part of the soil chemical analysis.

Special appreciation goes to Dr. Arthur N. Ott, a former employee of the Commission, who initiated this project in 1987 because he recognized the potential importance of field drains in the collection of agricultural chemicals and the discharge of these chemicals to the surface waters of the basin.

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ABSTRACT

Samples of ground water collected from wells located adjacent to a farm near Enterline, Pennsylvania have nitrate concentrations above expected background. The concentrations range from slightly more than 2 mg/l as N to nearly 12 mg/l as N in the test wells.

The average concentration of nitrate in test wells is highest in test well H2 (10.4 mg/l as N), the mid-slope well, and lowest in test well H1, the valley well (3.4 mg/l as N).

Analysis of the data indicates that the depth of the water-bearing zone below the water table contributing water to a well is a major factor in the measured nitrate concentration.

The field drain at the Enterline site flows only after heavy rains. The water from a significant storm (5/16-5/21/88) had a very high initial nitrate concentration (over 50 mg/l as N) which diminished rapidly to a fairly constant level of about 8 mg/l as N or approximately the same as in the ground water. This likely corresponded to a change in the primary source of water to the drain from surface water to ground water as the storm progressed and the ground-water level rose.

In contrast to the Enterline farm, only two of the five drilled wells on the Halifax farm (Wells C-1 and C-5) have yielded water having a concentration of nitrate above expected background.

A spring, which is located in the swale near the field drain monitoring site has consistently discharged water having a nitrate concentration of between 20 and 30 mg/l as N. The field drain discharges water having similar concentrations as the spring but has a wider flow range. Data indicate that the drain was installed at a depth which is below the ground-water table for much of the year. Thus the 20-30 mg/l nitrate measured in both the drain and spring probably represent the average nitrate concentration in the shallowest part of the ground-water flow system.

Because the field drain is below the water table, it is functioning similar to an interceptor ditch as described by Zheng and others (1988). Based on the analysis of precipitation and the discharge from the field drain and spring, almost all of the recharge to the ground water under the 10.9 acre basin draining to the swale was captured and discharged via the spring and field drain.

A small, artificial wetland was installed to treat the combined discharge from the field drain and spring. Samples collected on September 22, 1993 had nitrate concentrations of 24.0 mg/l as N and 0.55 mg/l as N from the inlet and outlet of the wetland, respectively.

INTRODUCTION

Ground water, discharging from agricultural areas, comprises a major source of nitrate in surface streams of the Susquehanna Basin. Nitrate from the Susquehanna River has been identified as a major factor contributing to the decline of water quality in the Chesapeake Bay.

A variety of tillage and cropping techniques, often called Agricultural Best Management Practices (BMPs), are commonly used in the Susquehanna basin to reduce surface runoff and the transport of nutrients (primarily nitrogen and phosphorus) to streams. However, many of the BMPs that are designed to reduce surface runoff (contour plowing, terracing, strip cropping, and no-till cultivation) cause an increase in the infiltration of precipitation to the ground-water system. Because the nitrogen from fertilizer or manure moves readily with the infiltrated water as dissolved nitrate, the BMPs can result in high concentrations of nitrate in the shallow ground water.

Ground water under agricultural sites generally flows downgradient from areas of recharge to the nearest stream valley where it discharges as baseflow to the stream. This downgradient flow can be interrupted by an artificial subsurface drainage system (tile or field drain). The field drains collect both surface and ground water from the fields and usually discharge it through a single outlet directly into ditches and feeder streams. Unlike surface runoff, which normally ends shortly after a precipitation event, tile drain systems may continue to flow long after a precipitation event, depending on the level of the water table. Because the ground water under farms is frequently contaminated by nutrients and pesticides, field drains may comprise a major conveyance for the removal of agricultural chemicals from farmland.

Purpose and Scope

This document is an update of information presented in three prior reports. The first two were unpublished interim reports that focused on the ground water under two farm sites and were dated October 31, 1988, and October 10, 1989. The third report presented a partial nutrient balance for the two small agricultural basins studied (Takita and others, 1991).

This report provides information on the quantity and quality of water discharging from the farms. Included are natural discharges (spring, ground water, and overland runoff) and discharges from man-installed field drains.

A constructed wetland, installed to remove nutrients from one of the field drain discharges, is also described.

Description of the Farms

The primary monitoring site is located on a farm about one and a half miles east of the Borough of Halifax (Figure 1.). The farming operation supports a 150 head dairy farm. Corn, the principal crop, is strip-cropped with alfalfa and rye. The monitoring facilities are located in cropped fields characterized by gentle to moderate slopes with drainage toward several swales.

The farmer (Clugston) uses a no-till planter for corn and adds a commercial starter fertilizer with the seed. The fields are almost entirely fertilized with dairy and chicken manure that are incorporated into the soil with a disc-harrow.

Much of the monitoring on a second farm located near Enterline has been discontinued because of a lack of coincidence between the ground- and surface-water basins. This made any quantitative analysis difficult. The operator of the Enterline farm (Harmon) typically applied commercial fertilizer and used minimum tillage to grow corn. During 1989, however, the fields were planted with a rye grass cover crop, without fertilizer or pesticide application. The fields have remained unplanted to the present. The former planted area consists of three fields (upper, middle, and lower) separated by wooded strips. Slopes range from relatively steep in the upper field to nearly flat in the lower field, which is in the flood plain of Powell Creek.

Sample Collection and Analysis

Monitoring systems were constructed during the spring of 1987 on each of the farms to measure the quantity and quality of the water discharged from the respective farms. The systems consist of pits that collect water from the tile drains and spring. These pits contain v-notch weirs and continuous water level recorders. Each site was equipped with an automatic water sampler to collect water samples at predetermined time intervals during storms.

Surface runoff monitoring systems were installed at the Halifax farm during the spring of 1988 and at the Enterline farm in the fall of 1988. The monitoring system on the Halifax farm consisted of a flume installed on a grassed waterway with wing-walls to direct all surface flows through the flume. A continuous stage recorder was installed to automatically record any flow through the flume during storm events. Water samples were collected automatically at prescribed time intervals. The monitoring system at the Enterline farm consisted of a weir and a continuous stage recorder installed in a drainage ditch at the edge of the field.

Initially, water discharge was sampled weekly and storm flows sampled hourly to determine changes in constituent concentrations over the course of storm events. The variations were found to be gradual so the sampling frequency was retained at weekly for non-storm samples and daily for storm samples. Surface runoff samples were collected automatically every hour since the runoff events were infrequent and of short duration.

Eight, six-inch diameter, monitoring wells were installed using an air rotary drill at the two farm sites during February 1988. In order to sample the shallowest possible ground water, drilling of the wells was terminated as soon as a measurable quantity of ground water was being blown from the well. In most instances, the wells had to be drilled substantially below the final measured water table before any water was obtained. The exception was well C5 which penetrated broken and weathered rock and produced water as soon as the water table was reached.

Most water occurred in the test wells following lithologic or color changes in the drilling cuttings which suggests that the water is produced primarily from openings between the beds.

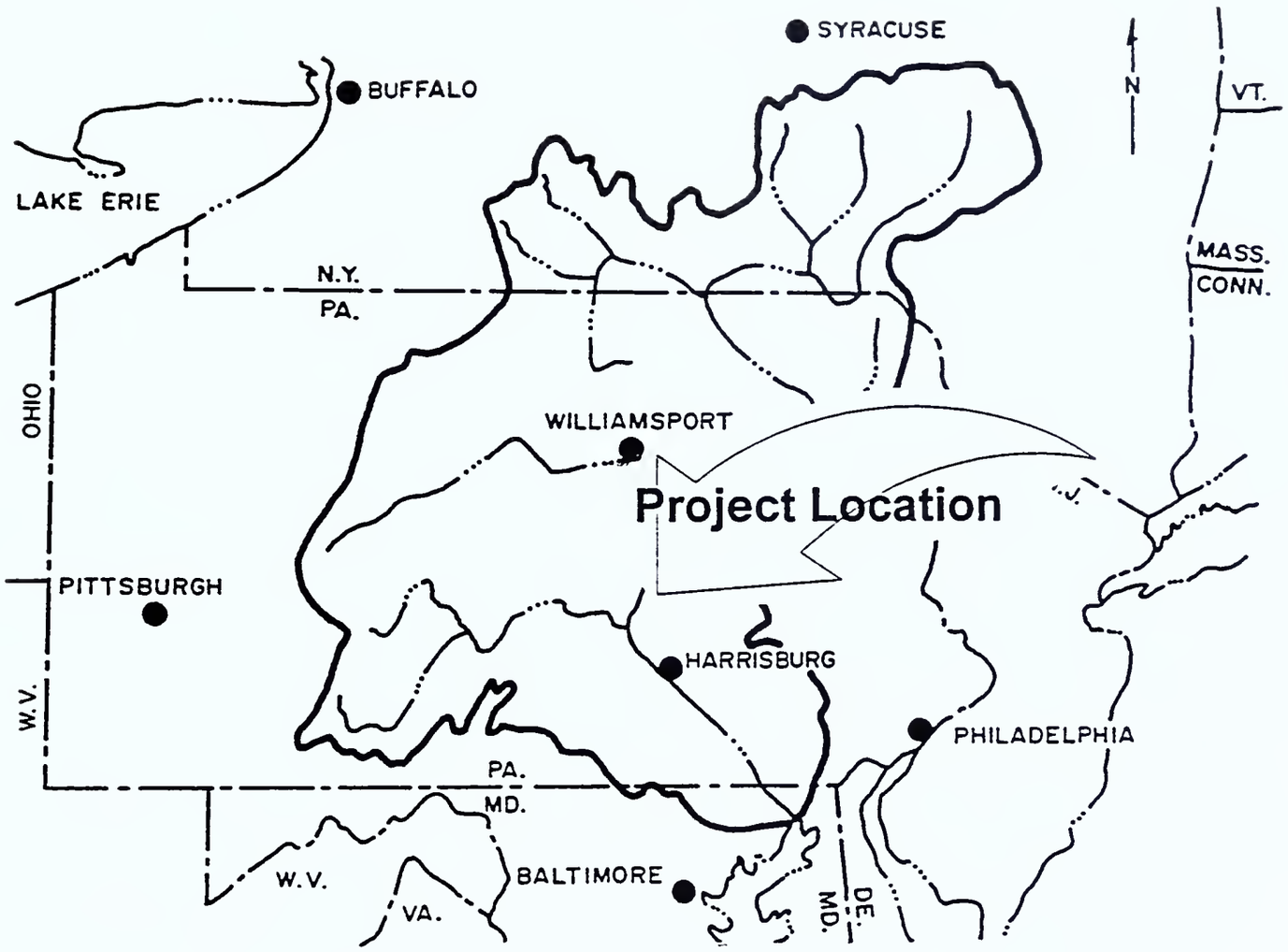

FIGURE 1. Location of the Farms Selected for Study.

The color of cuttings may change at lithologic boundaries (between beds) or where the rocks are differentially weathered as a result of ground-water flow.

The logs of the wells are presented in the Appendix. Depths range from 50 to 97 feet and estimated yields are from 7 gallons per minute (gpm) to a few pints per minute. All wells are cased to bedrock with the annular space around the casing sealed with bentonite.

The eight wells and two shallow auger holes were originally sampled on a monthly basis. Later, because of a lack of significant variation in the analytical results, selected wells were sampled quarterly and the remainder on an intermittent basis. Continuous water-level recorders are maintained on several of the wells. Figures 2 and 3 show the location of monitoring wells and field drain monitoring equipment. One set of samples was obtained from twenty domestic wells located on or adjacent to the farms. The locations of the sampled domestic wells at Halifax and Enterline are shown in Figures 4 and 5, respectively.

Most of the monitoring at the Enterline farm was discontinued during 1991 in order to focus our efforts on the Halifax site and further studies in the Armstrong Creek basin.

An observer at each farm site maintains records of daily precipitation.

PHYSIOGRAPHY AND GEOLOGY

The project area is located in a major valley within the Appalachian Mountain Section of the Valley and Ridge Physiographic Province. Drainage is to the Susquehanna River via Armstrong Creek (Halifax farm) and Powell Creek (Enterline Farm).

Bedrock at both locations is mapped as the Catskill Formation of Devonian age. The Irish Valley Member, which is comprised of alternating beds of light to medium gray sandstone, siltstone and shale with red siltstone and shale underlies the Halifax farm site. The strata strike about north 53 degrees east with a dip of approximately 30 degrees to the southeast. The Enterline Farm is underlain by the Sherman Creek Member which generally consists of interbedded red to grayish-red shale and siltstone with medium to dark red, very fine to medium-grained sandstone.

SOILS

Soils at the Halifax site vary from silt loams on the tops and sides of hills to a silty clay loam in the swale. The upland soils are moderately well drained and contain numerous rock fragments. Weathered bedrock is at a depth of two to three feet. The swale soils are considerably less well drained and consist of a dark reddish-brown, silty-clay loam surface layer with a moist gray and brown mottled zone occurring in a yellow-red clay loam from two to four feet deep. The field drain is located primarily within the swale and thus utilized to drain the excess moisture from the swale soils.

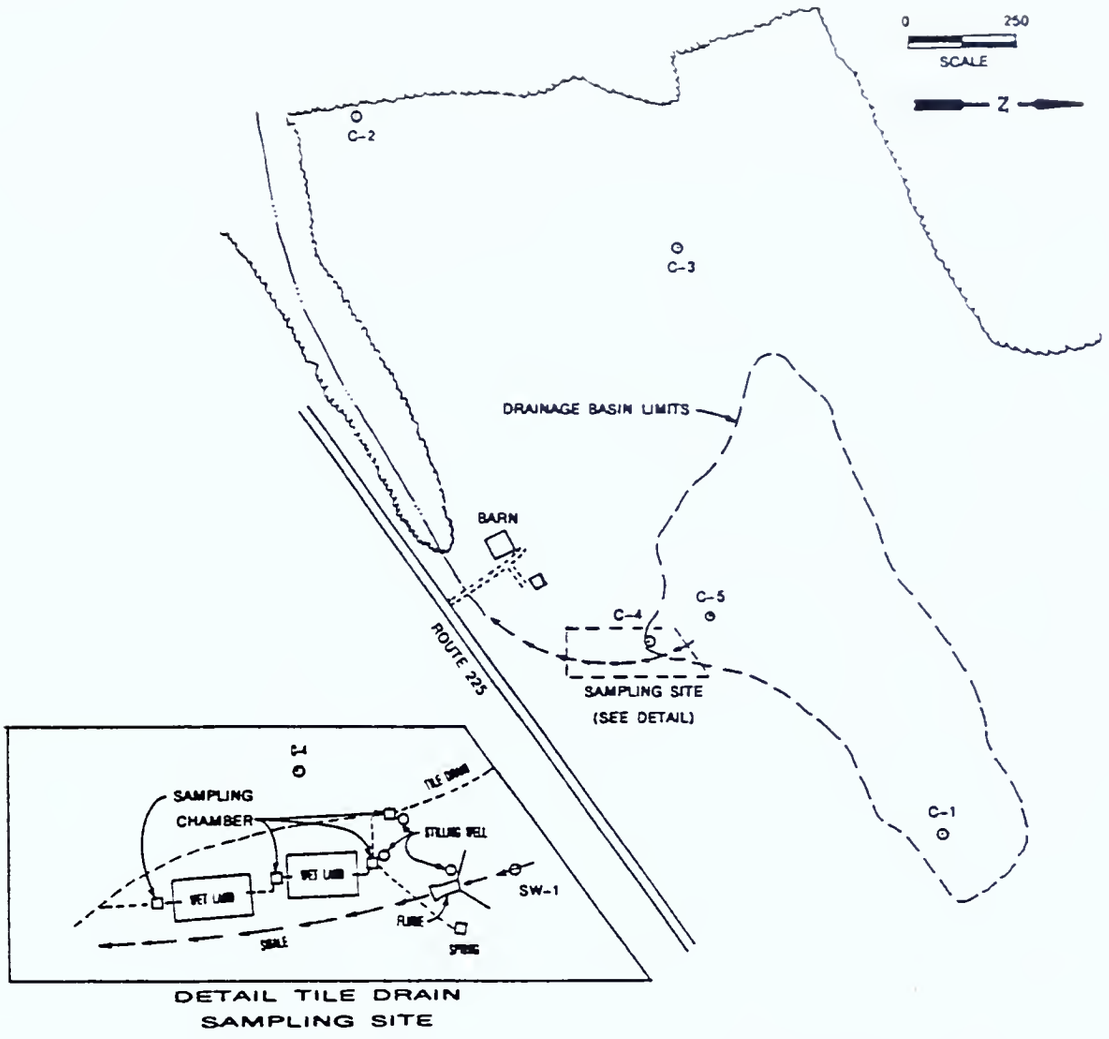

FIGURE 2. Location of Monitoring Facilities on the Halifax Farm.

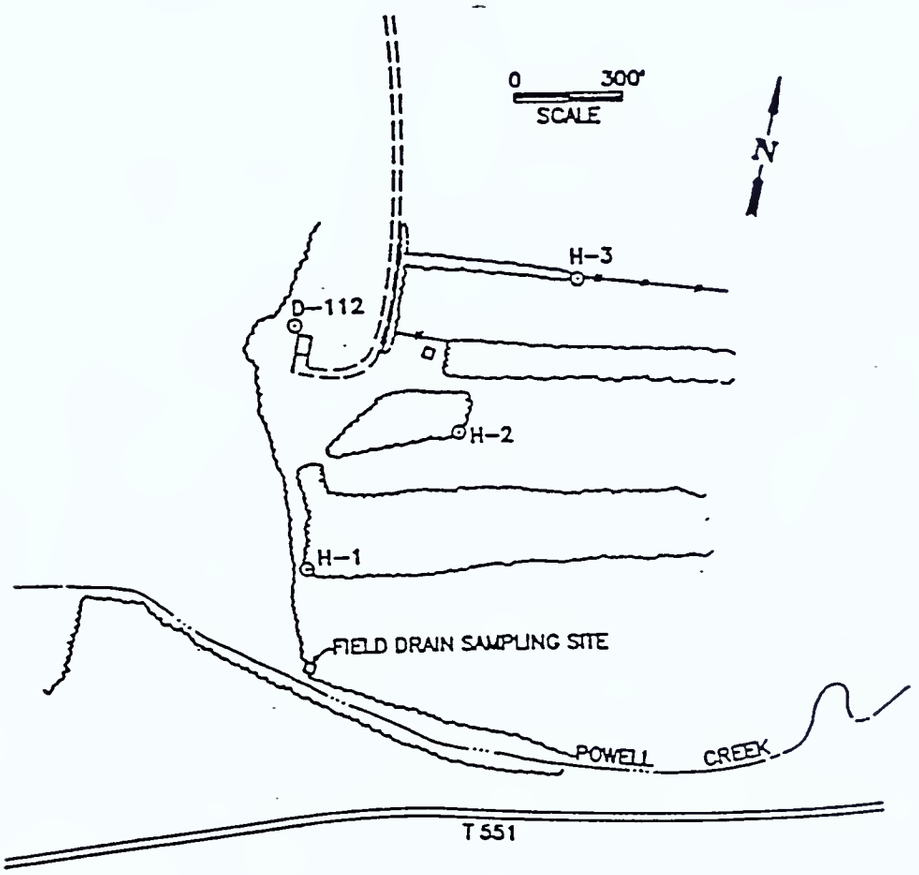

FIGURE 3. Location of Monitoring Facilities on the Enterline Farm.

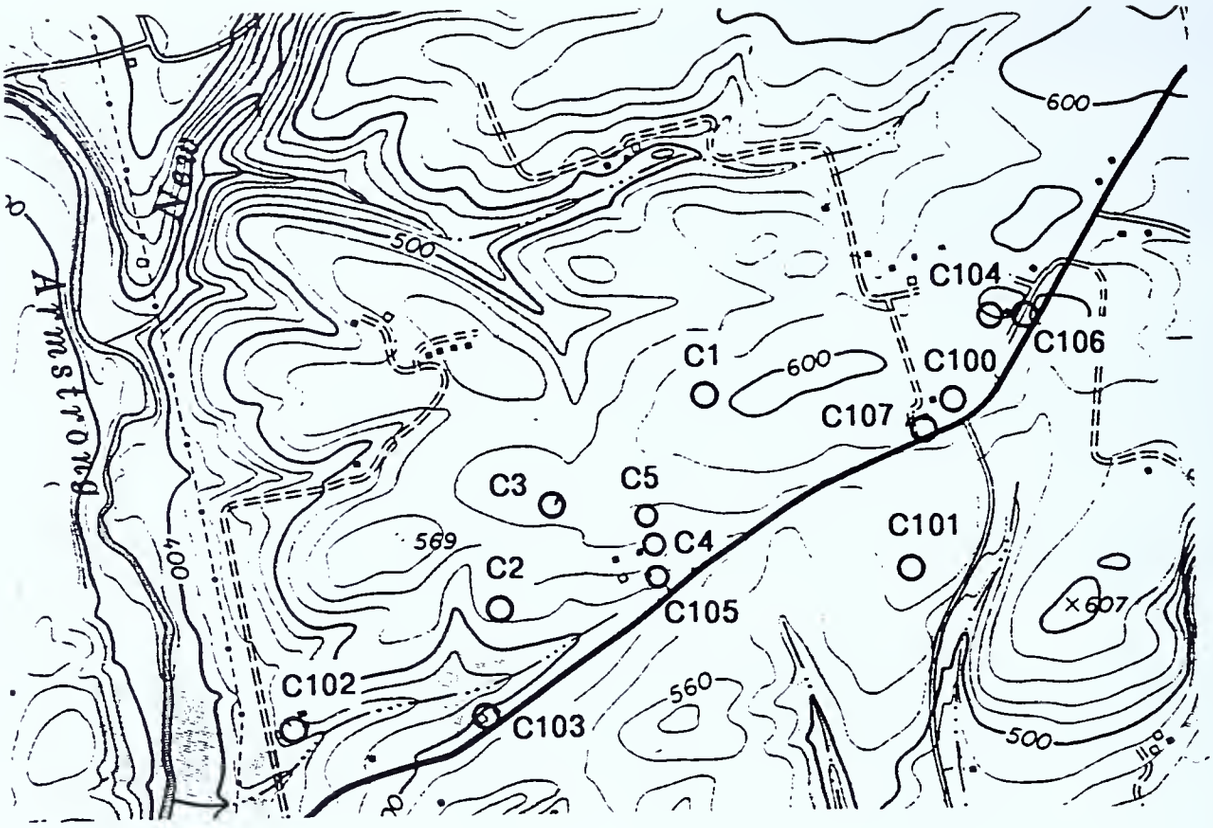

FIGURE 4. Location of Test Wells and Sampled Domestic Wells - Halifax Site

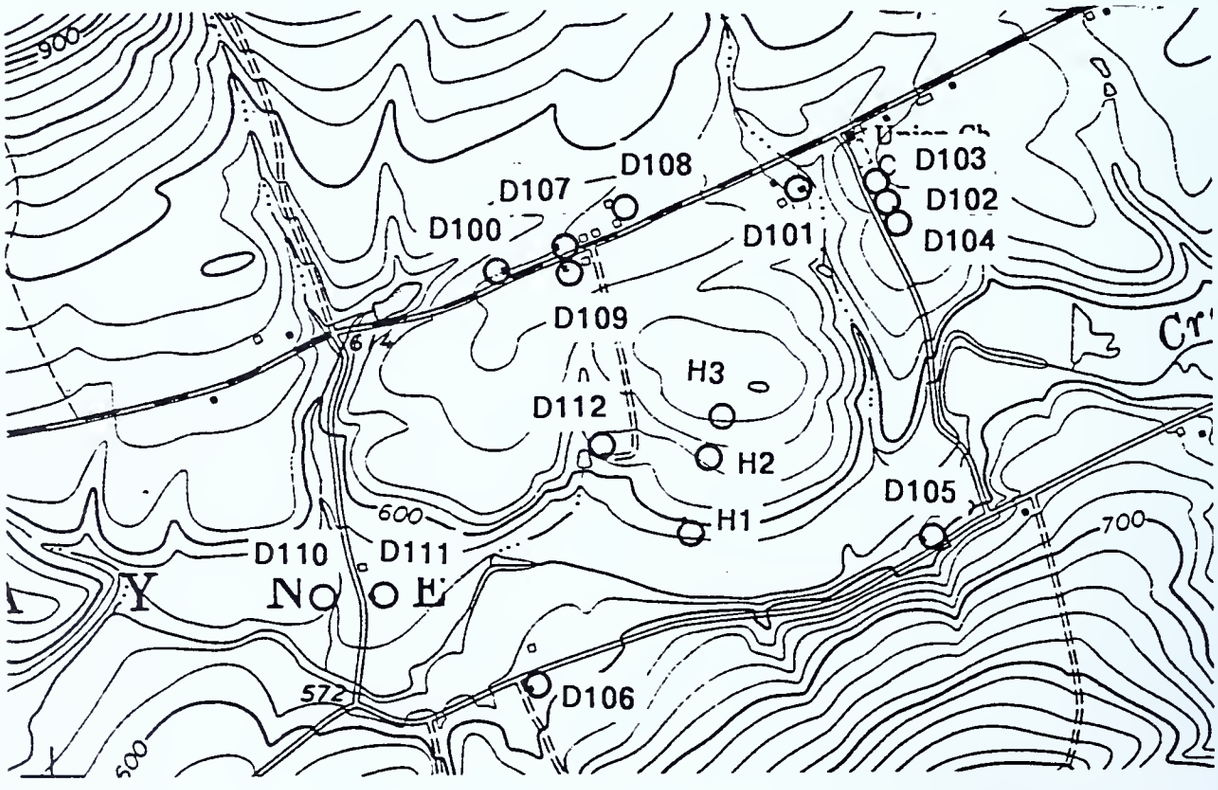

FIGURE 5. Location of Test Wells and Sampled Domestic Wells - Enterline Site.

Soils at the Enterline site grade from a channery sandy loam on the upper slopes to a silt loam on the flood plain of Powell Creek. The upper and middle slope soils are well drained and contain a medium to light brown, channery sandy loam surface layer and a medium orange to red channery loam subsoil. Weathered sandstone and siltstone bedrock occurs at a depth of about two feet. The silt loam on the flood plane is 10 inches thick in the auger hole used to monitor the shallow water table. Below this depth, the soil changes abruptly to a grayish-white and bright orange clay pan 39 inches thick. A thin layer of water bearing silty sand underlies the clay zone at 54 inches. This zone is thought to be the weathered top of the bedrock. The field drain here is used to remove the excess water from the flood plain soils. Also a gravel inlet allows surface runoff from the middle and upper fields to directly enter the drain during heavy storms.

PRECIPITATION AND CLIMATE

Annual rainfall averages about 40.2 inches in the Middle Susquehanna Section as designated by the National Weather Service. The average annual temperature is nearly 50 degrees F, and the growing season is about 160 days long and extends from May through September.

Precipitation during the nearly five year monitoring period has averaged 37.0 inches and 41.8 inches at the Halifax and Enterline farms, respectively (Tables 1. and 2.). Normal precipitation for the same time period, as calculated from the weather station at Selinsgrove, is about 40.1 inches.

GROUND WATER

Unweathered bedrock in the Catskill Formation is relatively impervious to water. Thus, most of the ground water in this rock unit is contained in secondary openings, fractures and bedding plane partings. Some may be contained within primary openings in the sandstone beds, however, this is considered to be minor.

Ground-water flow is dominantly local, with flow paths that are generally less than a few thousand feet. Recharge and discharge areas for a flow path are, for the most part, adjacent to one another.

The Formation generally yields sufficient quantities of water to wells for domestic and other uses requiring small to moderate supplies. The natural quality of ground water is adequate for most uses although many wells produce water containing high concentrations of iron and manganese (Taylor and Werkheiser, 1984).

WATER BUDGET

A water budget is a quantitative expression of the major components of the hydrologic cycle. Water that enters the hydrologic system as rainfall is balanced against the water that leaves the system as evapotranspiration and streamflow. In the case of the monitored farm

TABLE 1. Monthly and Total Precipitation at the Enterline Farm.						
Month	1987	1988	1989	1990	1991	1992
January		1.35	1.64	2.69	2.42	1.73
February		2.73	2.17	2.39	1.28	1.98
March		2.12	3.78	2.00	4.42	6.60
April		2.18	1.07	3.19	2.92	3.39
May		6.27	9.97	8.52	2.36	3.39
June		1.52	8.06	3.31	0.88	2.20
July	2.95	3.79	6.99	3.05	0.70	6.45
August	3.92	2.50	3.11	6.58	4.67	2.76
September	10.48	2.99	3.39	3.04	1.70	6.29
October	3.04	2.64	5.43	8.21	3.78	2.68
November	4.55	4.24	3.04	2.51	2.91	5.86
December	1.80	1.12	1.03	3.93	2.94	2.70
TOTAL		33.5	49.7	49.4	31.0	46.0

TABLE 2. Monthly and Total Precipitation at the Halifax Farm.						
Month	1987	1988	1989	1990	1991	1992
January		1.81	1.57	2.69*	2.67	0.71
February		2.54	1.60	1.65	1.23	1.52
March		1.86	2.63	0.97	2.01	4.28
April		1.75	1.10	2.44	2.72	3.37
May		4.92	8.33	6.86	2.14	2.63
June		1.73	7.09	2.68	0.35	2.39
July	2.66	3.45	9.47	3.07	1.55	6.28
August	3.10	3.14	3.95	5.33	5.31	1.46
September	13.09	3.40	3.32	3.86	1.38	4.43
October	2.54	1.83	4.93	6.18	2.61	0.66
November	3.29	3.99	1.93	2.43	2.78	5.86*
December	1.33	1.01	1.0*	6.32	2.81*	.97
TOTAL		31.4	46.9	44.5	27.6	34.6

* Estimated

basins, the water leaving the system consists of the field drain discharge, overland runoff, and ground-water underflow (ground water that bypasses the field drain).

Sufficient information has been collected at the Halifax farm to prepare a water budget for the small monitored basin. A similar analysis was not possible for the Enterline farm because of the lack of coincidence between the ground- and surface-water basins at that site.

Evapotranspiration

Evaporation from water bodies, wetted surfaces, and moist soil by direct evaporation; and vapor that escapes from living plants by the process of transpiration are collectively called evapotranspiration (ET). The amount of ET varies with the length of the growing season, the average temperature, and the amount and timing of precipitation and humidity. Consumptive losses to ET are at a minimum between the first killing frost in the fall and the active resumption of plant growth in the spring.

Taylor and Werkheiser provided a summary of annual ET estimates for several subbasins within the lower Susquehanna River Basin (1984, p.25). Evapotranspiration averaged 22.74 inches per year for the East Mahantango Creek Basin and 23.17 for the Swatara Creek Basin; two basins that adjoin the basins draining the farms.

The average monthly water loss at the Halifax site is shown in Figure 6. The water loss is calculated by subtracting the average monthly combined discharge of the spring and field drain from the average monthly precipitation. Water loss at this location consists of either evapotranspiration or ground water underflow that is not captured by the field drain or spring.

With the exception of June and November, the water loss shown in Figure 6. follows a pattern that is similar to the pattern that would be generated by plotting the average monthly temperatures. The evapotranspiration rate, which is directly related to temperature, would follow the same pattern.

Only a slight relation is apparent when the water loss is compared to the average monthly precipitation shown in Figure 7. Note that the total water loss is 22.6 inches which is very similar to the evapotranspiration estimates of Taylor and Werkheiser. Thus, on the average, almost all of the water losses can be attributed to evapotranspiration which means that ground water underflow is likely small. Most of the ground water recharge is likely being captured by the drain and spring.

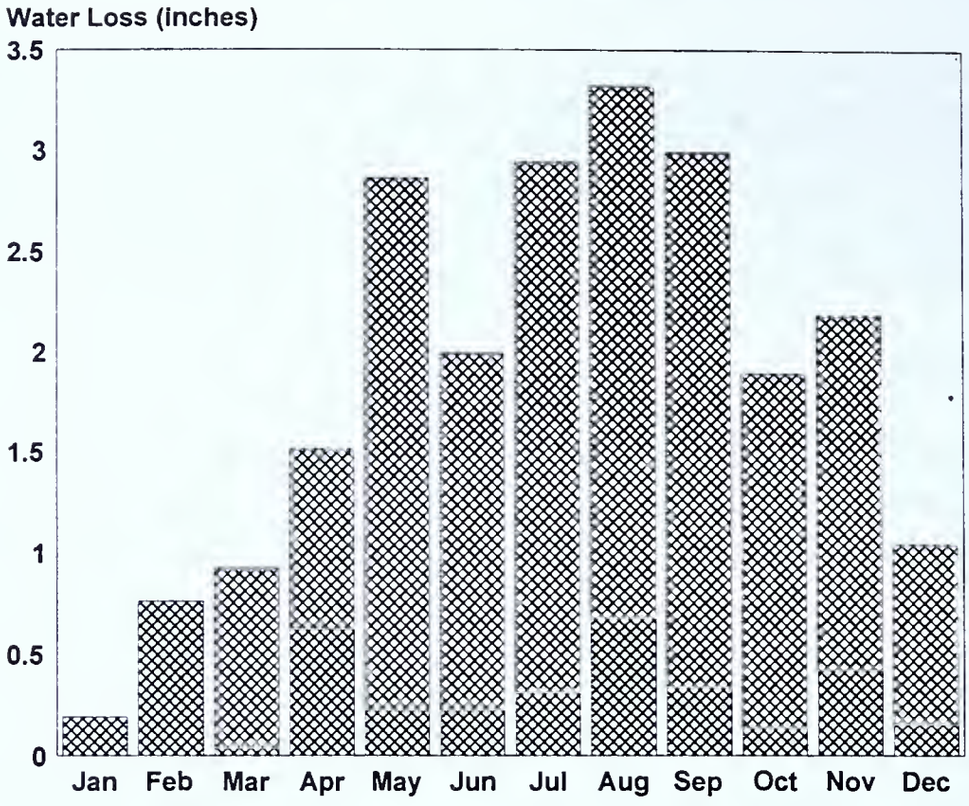

FIGURE 6. Average Monthly Water Loss, 1988 - 1992

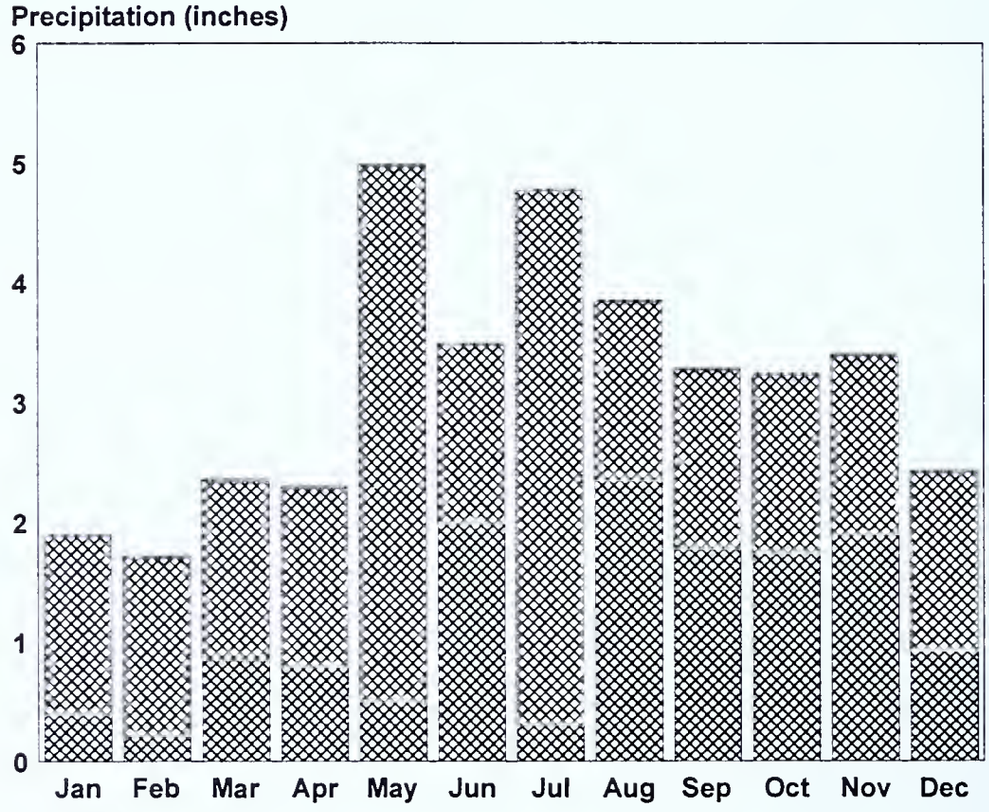

FIGURE 7. Average Monthly Precipitation, 1988 - 1992

Precipitation and Runoff

Annual records of precipitation, discharge from the field drain, spring, and flume are given in the Appendix, pages A7-A9. Total runoff measured at the field drain, spring, and flume has accounted for about 38 percent of the precipitation on the basin during the five and a monitoring period. Less than seven percent of the runoff was through the flume, suggesting that surface (or overland) runoff may be minor in this physiographic setting.

NITROGEN CHEMISTRY

Under natural conditions, the concentrations of dissolved nitrogen species in ground water are very low (the oxidized form of dissolved nitrogen, nitrate, is the most stable form in ground water). The background or natural concentration of nitrate in ground water from the Catskill Formation is about 0.4 milligrams per liter as N or less (Taylor and Werkheiser, 1984). Higher concentrations are generally a result of contamination from human activities. Commercial fertilizers, manure, and septic tank effluent are potential sources of organic and ammonium nitrogen that can eventually convert to nitrate and leach to the ground water.

The process by which ammonium nitrogen is converted to nitrate is called nitrification. Because the process is acidifying, one indication that nitrification has occurred is diminished, or lower than expected, concentrations of bicarbonate (bicarbonate participates in a buffering reaction with the hydrogen ions produced by nitrification; with the depletion of as much as 1 mole of bicarbonate as a result of the production of 1/2 mole of nitrate, Denver, 1986, p.27).

In reducing environments, volatilization of nitrogen can occur when nitrate is reduced to nitrous oxide or nitrogen gas by the process of denitrification. There is generally a tendency for ground water to change from being oxic (oxidizing) to anoxic (reducing) with depth and with distance along a flow path from recharge to discharge areas. Reducing ground water is generally characterized by low dissolved oxygen which can result in elevated concentrations of iron and manganese.

NUTRIENT CONCENTRATIONS - ENTERLINE FARM

The results of the chemical analyses from the three monitoring wells are listed in Tables 19 - 21 in the Appendix. Samples of ground water from all of the monitoring points have nitrate concentrations above expected background. The concentrations range from slightly more than 2 mg/l to nearly 12 mg/l as N in the test wells.

The average concentration of nitrate is highest in test well H2 (10.4 mg/l as N), the mid-slope well, and lowest in test well H1, the valley well (3.4 mg/l as N). This pattern was unexpected; in general, a gradual increase in nitrate concentration from recharge area (hilltop or hillside) to discharge area (valley) was thought likely, at least in the shallow part of the flow system. However, when the nitrate concentration in each well is plotted against the corresponding depth of water-bearing zone below the water table a linear relationship is apparent (Figure 8.). Well H-1 has the shallowest depth to water of slightly more than 9 feet, but has a

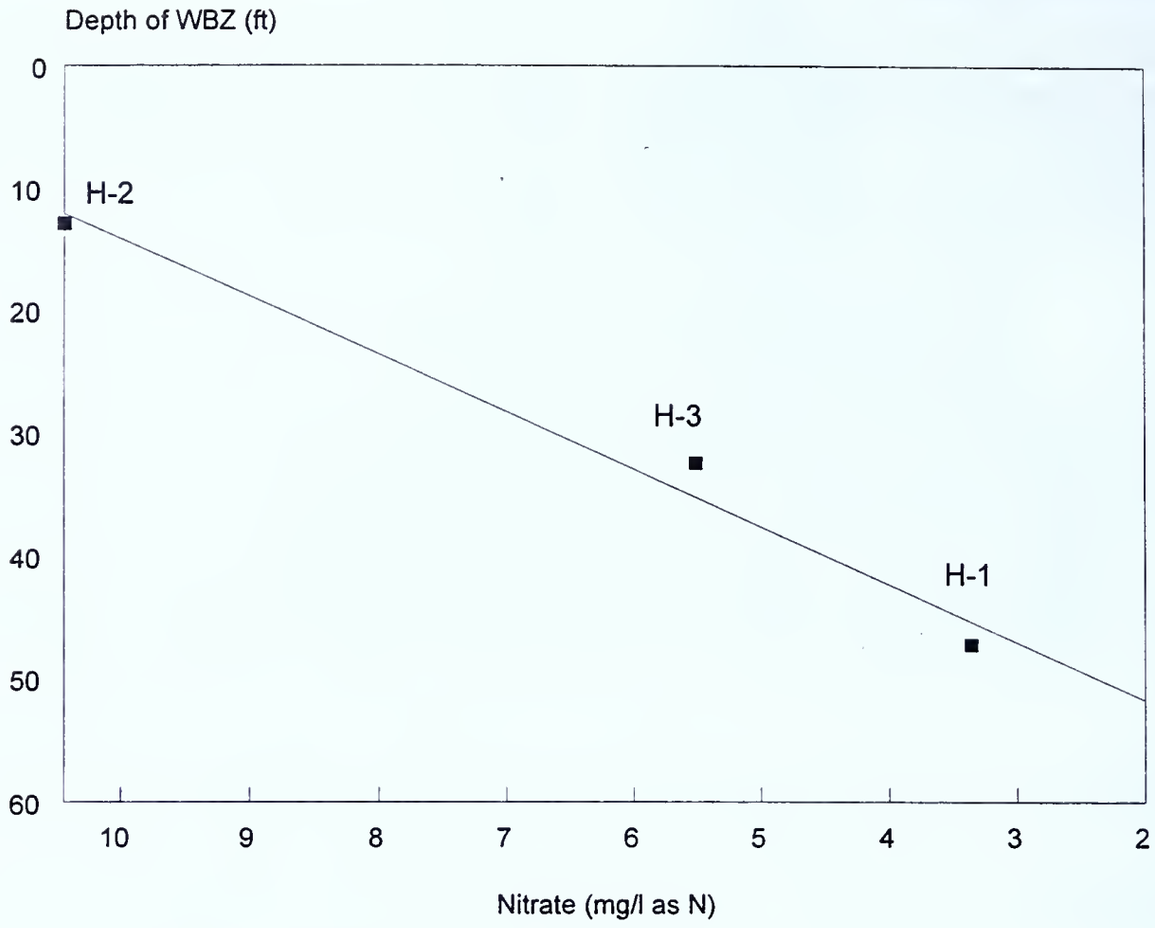

FIGURE 8. Relation of Average Concentration of Nitrate to Depth to Water-Bearing Zone Below the Water Table.

relatively deep water-bearing zone at 57 feet (difference of 48 feet) and the lowest nitrate. The water table is over 43 feet below the land surface in well H-2, but the water-bearing zone is only 13 feet below the water-table elevation and yields water containing the highest concentration of nitrate. The intermediate nitrate (5.5 mg/l as N) concentration occurs in ground water from H-3 which has the deepest water-bearing zone (97 feet) and also the deepest water table (about 65 feet) which equates to a difference of 32 feet.

Thus the depth of the water-bearing zone below the water table contributing water to a well appears to be a major factor in the measured nitrate concentration. There is likely a gradual decrease in nitrate concentration with increasing depth below the water table. Water samples collected from wells that do not have shallow water-bearing zones may not reflect the magnitude of ground-water contamination by nitrate.

The average alkalinity, primarily caused by the bicarbonate anion, is inversely related to the nitrate concentration. Water from well H-2 has the highest nitrate concentration (10.4 mg/l as N) and the lowest average alkalinity (10 mg/l) and well H-1 (3.7 mg/l as N) has the highest

(40 mg/l). This inverse relationship is a result of the process of nitrification and documents the important control nitrification has on the chemistry of the ground water in this area.

Chemical analyses of ground water from eleven nearby domestic wells are listed in Table 14., in the Appendix. The water from the domestic wells has a median nitrate concentration of 3.6 mg/l as N and a range of .39 mg/l to 15.8 mg/l as N. Few data were available on well depth and depth to water-bearing zones, thus no analysis of these factors is possible. These data show, however, that nitrate contamination of ground water is widespread in the vicinity of the Enterline farm. Only one sample, however, exceeds the US Environmental Protection Agency drinking-water standard of 10 mg/l as N.

The field drain at this site flows only after heavy rains. The water from a significant storm (5/16-5/21/88) had a very high initial nitrate concentration (over 50 mg/l as N) which diminished rapidly to a fairly constant level of about 8 mg/l as N or approximately the same as in the ground water. This likely corresponded to a change in the primary source of water to the drain from surface water to ground water as the storm progressed and the ground-water level rose.

NUTRIENT CONCENTRATIONS - HALIFAX FARM

Summary information about the chemical analyses from the five wells, in addition to the results of the domestic well sampling, is presented in the Appendix (Table 13 and Tables 15-19).

In contrast to the Enterline farm, only two of the five drilled wells (Wells C-1 and C-5) have yielded water having a concentration of nitrate above expected background. Well C-1 consistently yields water that exceeds the EPA drinking water standard of 10 mg/l. The median concentration of nitrate from C-5 is 12.7 mg/l as N and has ranged between 8.1 and 20.6 mg/l.

Analyses from Well C-1 illustrate one of the problems that occur when monitoring the quality of ground water in fractured-rock aquifers. Only one water-bearing zone, at a depth of 73 feet, was identified in the well during the drilling process. During the first year of monitoring (1988) static-water levels in the well were always deeper than 26 feet and the nitrate concentrations were near expected background levels. The highest measured concentration was 0.12 mg/l as N. Precipitation in 1988 was only 83 percent of normal, thus the water level in C-1 was abnormally low. About 124 percent of normal precipitation occurred during 1989, and as a result water levels in C-1 rose higher than the 26 foot depth by July. Results of the July sampling indicated that the nitrate concentration had also unexpectedly risen to 9.7 mg/l as N. On October 25, 1989, well C-1 was pumped for four hours and five samples were collected at time intervals shown in Figure 9. Note that there was a steady decrease in the nitrate concentration with time of pumping. Also, as the water level was drawn down by pumping, water could be heard to be flowing into the well at the 25 foot level. Apparently there is a second water-bearing zone in the well that only flows when the water table is high. This zone yields water that is high in nitrate. As the well is pumped, and the shallow zone is gradually dewatered, a larger fraction of the water is obtained from the deeper zone. This accounts for the gradual decline in the nitrate concentration with time of pumping.

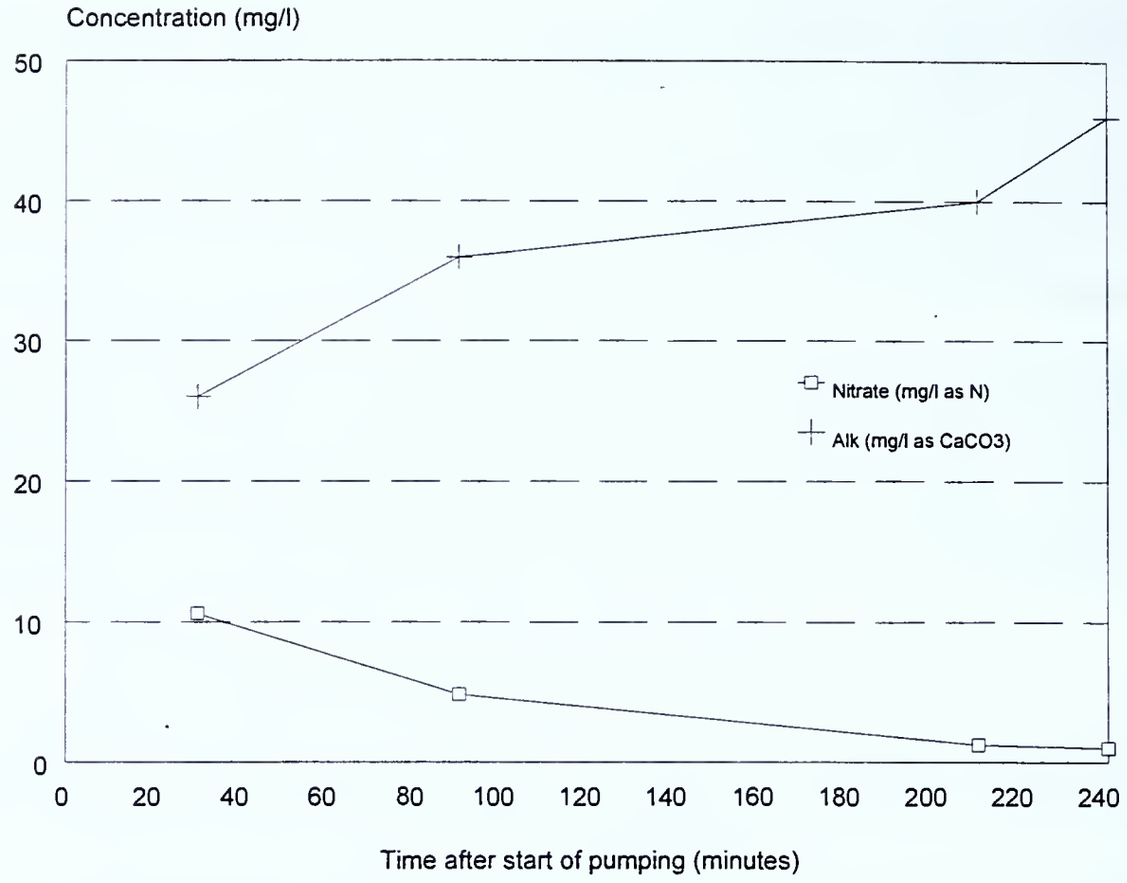

FIGURE 9. Concentration of Nitrate and Alkalinity in Well C-1

The primary implication of this finding is that only those wells that have shallow water-bearing zones are likely to show the effects of agricultural contamination. If the only wells monitored have either deep casing or deep water-bearing zones, then contamination by agricultural chemicals could be missed.

The nitrate concentrations in water from the other four wells on the Halifax farm have ranged from 1.85 mg/l to below the laboratory detection limit of 0.04 mg/l as N. Because all of these wells have comparatively deep water-bearing zones, the results are inconclusive with respect to the concentration of nitrate in the shallow ground water.

The spring, which is located in the swale near the field drain monitoring site has consistently discharged water having a nitrate concentration of between 20 and 30 mg/l as N, with only a very few analyses having higher or lower concentrations. The field drain discharges water having similar concentrations as the spring but has a wider flow range. The uniformity of the nitrate concentrations, and the concentrations of other chemical constituents, is more characteristic of a ground water, rather than surface water, source for the flow. Additionally, the drain and the spring continue to flow during extended dry periods. These observations indicate

that the drain was installed at a depth which is below the ground-water table for much of the year. In fact, water levels in well C-5, which is also in the swale, can be used to predict when the drain will and will not flow. Thus the 20-30 mg/l nitrate measured in both the drain and spring probably represent the average nitrate concentration in the shallowest part of the ground-water flow system.

The concentration of nitrate in the ground water from well C-5 is about half that of the spring and drain. When drilled, the well produced water almost as soon as the water table was penetrated, however, an additional water-bearing zone was observed at a depth of approximately 42 to 46 feet. Water from this deeper zone is probably significantly lower in nitrate than that contained in the shallower zones. Thus, pumped samples from the well may represent an average ground-water quality of at least two zones, which could account for the relatively low nitrate concentration. Note that in well C-4, which is located within a few feet of the field drain, a water-bearing zone was not penetrated until a depth of 65 feet was reached. The water pumped from C-4 contains an average nitrate concentration of 0.06 mg/l as N.

An interesting aspect of the field drain being below the water table is that it may be functioning similar to an interceptor ditch as described by Zheng and others (1988). The most widespread use of interceptor ditches is to collect shallow ground water in aquifers where pollutants are concentrated near the water table such as the cleanup of oil spills and agricultural chemicals. The effectiveness of an interceptor system is due to the fact that it creates an hydraulic barrier which captures polluted ground water from upgradient sources in an aquifer, thereby preventing the polluted water from moving further down gradient.

Based on the analysis of precipitation and the discharge from the field drain and spring, almost all of the recharge to the ground water under the 10.9 acre basin draining to the swale was discharged via the spring and field drain. Although this estimate may be high, clearly a significant part of the shallow ground water, and likely the most contaminated part, is captured by the field drain and spring. Of course, this shifts the contaminated water from the subsurface to the surface and has the potential to directly contaminate surface water. Because the nutrient rich water is concentrated at one discharge point, however, the potential now exists for treatment or use of the water. A later section in this report describes the use of a small wetland to treat the field drain discharge.

Eight domestic wells located on or near the farm were inventoried and sampled. Again, all of the analyses except one have nitrate levels near the expected background for the Catskill Formation. The exception was well C-103, which produced ground-water having a nitrate concentration of 13.2 mg/l. No reason for this high level of nitrate could be determined, although the well is assumed to be quite old and may produce from shallow zones. There is no data available, however, to substantiate this assumption.

PESTICIDES

Ground water from well H-2 had 0.38 ug/l (micrograms per liter) of the pesticide metalachlor (commercially known as Dual) in the August 1988 sample and 0.36 ug/l in the

August 1989 sample (although none was applied in 1989). Pesticides were not detected in samples from wells H-1 and H-3.

Samples collected during 1990 and 1991 from the Halifax field drain did not have detectable amounts of the target pesticides.

INTERPRETATION OF RESULTS

Agricultural field drains, used to eliminate poorly drained or wet areas in cropped fields, often function similar to interceptor ditches in forming hydraulic barriers and prevent contaminated ground water from moving beyond the drain. This occurs when the field drain is either intentionally or unintentionally installed below the natural ground-water table.

Based on the analysis of precipitation and the discharge from the field drain and spring, a quantity of ground water equivalent to almost all of the recharge to the monitored basin is being collected by the drain. The discharged water averages about 20 to 22 milligrams per liter of nitrate as nitrogen, which is about twice the EPA standard for drinking water. The field drain, however, shifts the contaminated water from the subsurface to the surface, which can contribute to surface-water contamination unless treated.

Ground water underlying the Halifax farm occurs in two distinct geochemical zones. The shallow part of the ground water flow system is the oxic zone and is characterized by high concentrations of nitrate and dissolved oxygen, and relatively low concentrations of iron, manganese, and alkalinity. The deep part of the flow system is the anoxic zone and characterized by very low dissolved oxygen and nitrate and high concentrations of iron, manganese, and alkalinity (Figure 10).

Postma and others name the boundary between these zones as the redoxcline (1991. p. 2030), and provide several generalizations about the zones that are useful in interpreting the geochemistry of the farm site. First, the sharp decline in nitrate concentration at the redoxcline indicates that nitrate reduction is taking place. The near absence of nitrate and ammonia suggests that nitrogen gas is the dominant reduction product.

Second, the additions of large amounts of nitrate, should increase the downward progression of the redox front. They suggested that the pyrite content of the bedrock may be a major controlling factor on the downward migration of the redox front; and that at concentrations above 10 mmol/kg pyrite, the redox front progression becomes insignificant on a human time scale. No information was obtained in the current project on the concentration of pyrite in the bedrock.

WETLAND TREATMENT SYSTEM

The field drain on the Halifax farm is diverting the contaminated ground water to the surface and consequently contributing to surface-water contamination. Several options were proposed to treat the contaminated water from the drain, These included recycling the water

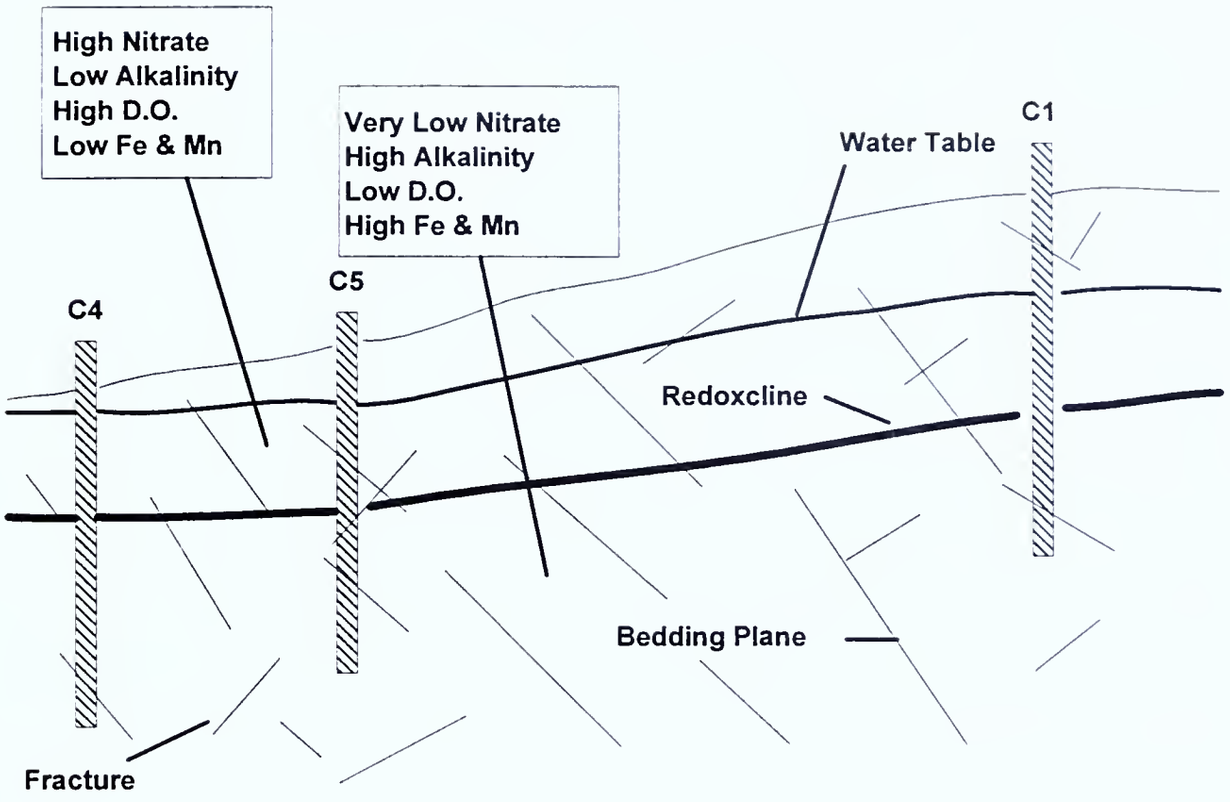

FIGURE 10. Idealized Cross Section Through Part of the Halifax Farm.

back to the fields or using the water in some type of "aquaculture" project. After reviewing the alternatives, a wetland treatment system was selected for three reasons: (1) Wetlands have been successfully used to remove nutrients from sewage treatment plant effluent; (2) A small wetland could be installed at a relatively low cost; and (3) A wetland is a "passive" system that requires little or no maintenance by the farmer.

Design

The wetland was constructed at the approximate location shown in Figure 2. The wetland consists of a small, excavated basin approximately 20 feet wide by 50 feet long, with a depth of about 3 feet. The basin was primarily filled with poorly sorted, sand size, crushed stone. A layer of very coarse crushed stone was spread on the surface to prevent any free water from occurring. The basin was lined with plastic to prevent infiltration of water from the wetland to the ground water. Cattails were selected as the wetland vegetation because of their widespread availability.

The treatment process consists of directing the flow from the field drain through a box containing a v-notch weir. This box is used for collecting water-quality samples and measuring inflow to the wetland. An additional box and weir were installed at the outlet of each wetland cell to provide an additional monitoring point and enable control of the water level in the cells.

Effectiveness

Tables 27 and 28, in the Appendix, provide a summary of water quality data from the inlet and outlet of the wetland. Although there had been a small reduction in the nitrate in the discharge from the wetland, we were dissatisfied with the results. Review of the data suggested that the concentration of phosphorus in the spring and field drain might be inadequate to promote root growth. In June of 1993, a phosphorus fertilizer was added to the wetland. Within three weeks the nitrate concentration in the wetland discharge dropped from 24.0 mg/l as N to 9.24 mg/l as N. Also the dissolved oxygen fell from 2 mg/l to essentially zero. The initial samples from the two cell wetland, collected on September 22, 1993 had nitrate concentrations of 24.0 mg/l as N and 0.55 mg/l as N from the inlet and outlet of the combined wetland cells, respectively. These data are quite promising, and suggest that the wetland may now be attaining the initially anticipated reduction in nitrate.

CONCLUSIONS

Considerable water-quality data has been collected from the two farms and several interpretations can been made:

1. Nitrification is an important process influencing the quality of recharge to the ground water system at both farm sites.

2. The nitrate concentration in ground water decreases with increasing depth below the water table. Thus, the depth to the shallowest water-bearing zone is an important factor in determining the degree that the quality of ground water produced by a well will be influenced by agricultural activities.

3. In the rolling topography, as characterized by areas underlain by the Catskill Formation, field drains can be designed to capture a significant portion of the recharge to the ground water system; perhaps limiting the spread of nutrient contaminated ground water. The nutrient rich water can be treated using small, artificial wetlands.

4. Application timing and rates, and types of fertilizer may be important factors in the quality of recharge water, however, soil conditions, depth of water table, depth of water-bearing zones, and natural chemical character of the ground water (either oxic or anoxic) are important considerations with respect to the degree the ground water will be contaminated.

RECOMMENDATIONS

Concepts developed from the existing project should be utilized in a study of the entire Armstrong Creek basin. From this, estimates could be made of the potential nutrient reduction that could be obtained by collecting and treating localized ground-water discharges using field drains and constructed wetlands.

The constructed wetland on the Clugston farm was designed based on the average field drain flows that occurred during the first two years of the project (two relatively dry years). More recent monitoring data, collected during years with higher precipitation, suggest that a larger wetland would provide a longer retention time and a larger reduction in nitrate. Thus, a second wetland cell should be added to the Clugston farm wetland and monitored for effectiveness. Also, based on lessons learned during the original wetland construction, changes should be made in the fill material and carbon source.

The effectiveness of the field drain in the prevention of down-gradient ground-water contamination needs to be further analyzed, possibly by developing a cross-sectional model of the site.

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TABLE 3. Annual Nutrient Load Discharged from the Halifax Farm Field Drain, Spring, Surface Flow, and the Combined Runoff

Time Period	Tile Drain				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
Sep - Dec 1987	1.16	1.88	1.51	227	1.5
1988	0.602	1.07	0.11	99.8	2.0
1989	4.02	9.71	0.58	770	1.8
1990	1.51	21.9	0.537	858	0.902
1991	1.84	1.89	0.323	218	0.385
1992	1.72	4.18	0.370	351	0.416

Time Period	Spring				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
Sep - Dec 1987	0.396	0.90	0.07	81.3	0.07
1988	0.806	1.02	0.09	137	0.24
1989	1.79	2.76	0.20	342	0.70
1990	0.981	7.14	0.154	363	0.428
1991	1.38	15.3	0.222	256	0.309
1992	1.97	3.16	0.359	427	0.355

Time Period	Surface				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
1989	0.632	9.08	0.70	85.1	3.36
1990	0.828	17.7	0.690	20.4	7.99
1991	0.021	0.159	0.013	2.45	0.047
1992	--	--	--	--	--

Time Period	Combined Runoff				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
Sep - Dec 1987	1.56	10.8	1.58	308	1.60
1988	1.41	2.09	0.2	237	2.24
1989	6.44	21.6	1.48	1,200	5.86
1990	3.32	46.7	1.38	1,240	9.32
1991	3.24	17.3	0.558	476	0.741
1992	3.70	7.34	0.729	778	0.766

TABLE 4. Annual Nutrient Load Discharged from the Enterline Farm Field Drain, Surface Flow, and Combined Runoff

Time Period	Tile Drain				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
Jul - Dec 1987	2.05	5.26	0.760	154	1.39
1988	1.43	3.55	1.85	97.7	2.63
1989	2.85	5.63	0.330	224	0.940
1990	3.13	7.87	0.442	190	0.625
1991	2.00	3.35	0.494	102	0.428
1992	1.40	1.98	0.432	58.8	0.318

Time Period	Surface				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
1989	0.584	2.30	0.170	19.4	0.460
1990	0.954	3.00	0.150	53.8	0.456
1991	0.120	0.200	0.050	6.78	0.040
1992	--	--	--	--	--

Time Period	Combined Runoff				
	Total Q (Mgal)	TKN (lbs)	NH_3-N (lbs)	NO_{2-3}-N (lbs)	TP (lbs)
Jul - Dec 1987	2.05	5.26	0.70	154	1.39
1988	1.43	3.55	1.85	97.7	2.63
1989	3.43	7.93	0.500	243	1.40
1990	4.08	10.9	0.592	244	1.08
1991	2.12	3.55	0.544	108	0.884
1992	1.40	1.98	0.432	58.8	0.318

TABLE 5. Annual Discharge and Nutrient Loads from the Constructed Wetland						
Year Source	Total Q (gal)	TKN (lbs)	NH3-N (lbs)	NO2-3 N(lbs)	TP (lbs)	TOC (lbs)
1990						
Inlet	2,490,000	6.5	0.208	476	0.654	21.8
Outlet	2,490,000	219	0.523	473	0.654	24.8
1991						
Inlet	3,220,000	5.73	0.516	575	1.01	33.0
Outlet	3,220,000	5.21	0.882	564	0.935	36.1
1992						
Inlet	3,700,000	7.62	0.729	769	0.830	37.8
Outlet	3,700,000	8.34	0.824	688	0.653	40.8

Note: Results are for Oct-Dec 1990

TABLE 6. Logs of Test Wells				
Well ID	Date Drilled	Casing Length	Depth Interval (ft)	Description
C1	2/16/88	20	0-5	Soil; medium brown to red silt
			5-41	Siltstone; dark red, fine texture increasing medium texture with depth
			41-60	Siltstone and sandstone; gray, fine grained
			60-64	Sandstone; brownish-gray, fine grained
			64-73	Sandstone and siltstone; gray, fine grained
			73-90	Siltstone; dark red, water @ 73 ft.
C2	2/17/88	20	0-3	Soil; light brown, to tan silt loam
			3-5	Siltstone; light brown, weathered
			5-18	Siltstone; olive brown, weathered
			18-32	Siltstone; light gray bright
			32-33	Sandstone; light gray, fine grained with iron straining, water, brownish color change
			33-50	Sandstone; light gray, fine grained

TABLE 6. Logs of Test Wells (Continued)				
Well ID	**Date Drilled**	**Casing Length**	**Depth Interval (ft)**	**Description**
C3	2/17/88	20	0-3	Soil; yellowish-orange silt loan
			3-13	Siltstone; orange to red, weathered
			13-18	Siltstone; red, some light gray
			18-30	Siltstone; red and light gray with some interbeds of very fine grained sandstone
			30-40	Siltstone; reddish-gray, more uniform
			40-52	Siltstone and sandstone; red, fine grained
			52-55	Sandstone; gray, fine grained, water @ 53 ft.
			55-65	Sandstone; dull red, fine grained
C4	2/17/88	20	0-3	Soil; medium red silt loam
			3-12	Siltstone; medium red, weathered
			12-32	Siltstone; dull red
			32-35	Siltstone and sandstone; olive gray, fine grained
			35-52	Sandstone; dull red, fine grained
			52-80	Siltstone and sandstone; light gray, fine grained, water @ 62 ft.
C5	2/18/88	30	0-4	Soil; light to dark brown silt loam
			4-9	Soil; light brown-tan silt clay, rock fragments
			9-22	Soil; tan to brown
			22-32	Siltstone and sandstone; tan to red, fine grained, weathered
			32-50	Sandstone; red, fine grained, 42-46 feet fractured zone
H1	2/15/88	20	0-5	Soil; medium orange-brown, sandy silt loam
			5-15	Sandstone and siltstone; red, fine grained, weathered, water @ 8 ft.
			15-40	Siltstone; red with trace of sandstone
			40-58	Sandstone; brownish red, medium grained
			58-65	Sandstone; as above with interbeds of sandstone and siltstone; olive gray, fine to medium grained, water @ 58 ft.

TABLE 6. Logs of Test Wells (Continued)				
Well ID	**Date Drilled**	**Casing Length**	**Depth Interval (ft)**	**Description**
H2	2/15/88	20	0-10	Soil; light red-brown sandy silt
			10-16	Sandstone; red, fine grained, weathered
			16-25	Sandstone; red, medium grained
			25-55	Siltstone, red
			55-85	Sandstone and siltstone; red, fine grained, color change to brownish-green at 60 ft.
			85-97	Sandstone; dark red. fine to medium grained, little water @ 95 ft.
H3	2/16/88	20	0-10	Soil; light orange-brown channery sandy loam
			10-20	Sandstone and siltstone; light to medium red, very fine grained
			20-42	Sandstone; dark red, medium grained
			42-45	Sandstone; medium gray, medium grained, some clean white grains
			45-59	Siltstone; dark red
			59-65	Sandstone; dark red, fine to medium grained with sandstone; medium gray
			65-92	Siltstone; medium red, dirty, little water @ 68 ft.
			92-95	Siltstone and sandstone; as above with sandstone; very dark gray

TABLE 7. Precipitation and Runoff from the Halifax Farm, 1987					
	10^3 gallons				
Month	Precip-itation	Field Drain	Spring	Surface	Total Discharge
September	3,610	693	5.90	--	699
October	703	19.2	76.9	--	96
November	910	275	151	--	426
December	368	173	159	--	332
Total	5,600	1,160	396	--	1,550

TABLE 8. Precipitation and Runoff from the Halifax Farm, 1988					
	10^3 gallons				
Month	Precip-itation	Field Drain	Spring	Surface	Total Discharge
January	501	56.5	40.7	0	97.2
February	703	68.4	246	0	314
March	515	120	110	0	230
April	484	23.7	25.8	0	49.7
May	1,360	153	122	0	275
June	479	52.6	56.7	0	109
July	955	13.2	28.4	0	41.6
August	870	.156	17.5	0	17.7
September	941	0	13.3	0	13.3
October	507	0	4.31	0	4.31
November	1,100	96.8	106	0	203
December	280	17.9	35.6	0	53.5
Total	8,700	602	806	0	1,410

TABLE 9. Precipitation and Runoff from the Halifax Farm, 1989					
	10^3 gallons				
Month	Precip-itation	Field Drain	Spring	Surface	Total Discharge
January	435	81.7	127	0	209
February	443	48.7	75.8	0	125
March	728	300	175	0	475
April	305	64.5	112	0	177
May	2,310	927	279	0	1,210
June	1,960	476	181	49.0	706
July	2,620	1,230	385	307	1,920
August	1,090	233	128	0	361
September	919	39.6	54.1	0	97.3
October	1,360	455	129	153	737
November	531	144	103	0	247
December	277*	17.4	43.5	123	184
Total	12,700	4,020	1,790	632	6,440

TABLE 10. Precipitation and Runoff from the Halifax Farm, 1990					
	10^3 gallons				
Month	Precip-itation	Field Drain	Spring	Surface	Total Discharge
January	744	290	61.2	458	809
February	456	298	229	0	527
March	268	108	64.8	0	173
April	695	202	132	0	334
May	1,900	1,060	125	3.80	1,190
June	741	659	209	2.40	870
July	849	111	59.9	307	478
August	1,470	128	66.7	0	195
September	1,070	134	90.9	0	225
October	1,710	835	140	20.7	996
November	672	245	126	.451	822
December	1,750	726	268	39.4	1,030
Total	12,300	4,795	1,572	829	6,920

TABLE 11. Precipitation and Runoff from the Halifax Farm, 1991					
	10^3 gallons				
Month	Precip-itation	Field Drain	Spring	Surface	Total Discharge
January	739	696	296	21.4	1010
February	340	126	112	0	238
March	556	245	205	0	450
April	752	56.1	167	0	223
May	592	14.2	103	0	117
June	96.8	1.38	31.2	0	32.6
July	429	0	16.6	0	16.6
August	1,470	4.31	49.1	0	53.4
September	382	0	21.4	0	21.4
October	722	0	6.98	0	6.98
November	769	6.43	53.3	0	59.7
December	777	45.9	203	0	252
Total	7,630	1,190	1,260	21.4	2,480

TABLE 12. Precipitation and Runoff from the Halifax Farm, 1992					
	10^3 gallons				
Month	Precip-itation	Field Drain	Spring	Surface	Total Discharge
January	196	35.7	193	0	229
February	420	40.2	74.7	0	115
March	1,180	337	312	0	649
April	932	86.1	203	0	289
May	727	31.2	115	0	146
June	661	2.63	41.4	0	44.0
July	1,740	28.8	52.3	0	81.1
August	404	18.9	70.3	0	89.2
September	1,225	16.0	33.8	0	49.8
October	182	13.0	104	0	117
November	1.620	150	194	0	344
December	268	128	269	0	397
Total	9,570	888	1,660	0	2,550

TABLE 13. Chemical analyses of ground water from domestic wells in the Halifax area

Halifax Area

ID	DATE	COND	pH	ALK mg/l	DISS. SOLID mg/l	NO2-N mg/l	NO3-N mg/l	HARD mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l
C-102	880721	184	6.7	72	128	0.004	1.48	56	12.3	7.17	12.7	0.65	5	22
C-103	880721	435	6.4	40	372	<0.004	13.2	134	25.9	16.2	17.2	1.95	92	24
C-104	880721	155	7.0	82	120	0.004	0.04	56	12.4	7.62	9.95	0.58	<1	15
C-106	880726	160	6.8	76	164	<0.004	0.12	56	9.84	9.34	10.6	0.90	2	11

ID	DATE	F mg/l	Al ug/l	As ug/l	Ba ug/l	Cd ug/l	Cr ug/l	Fe ug/l	Pb ug/l	Mn ug/l	Ni ug/l	Sr ug/l	Zn ug/l
C-102	880721	<0.10	<135	<100	116	<10	<50	149	86	25	59	253	22
C-103	880721	<0.10	<135	<100	216	<10	<50	150	52	<10	68	148	57
C-104	880721	0.13	<135	<100	313	<10	<50	19	<50	259	<25	152	17
C-106	880726	0.14	157	<100	353	<10	<50	178	<50	256	<25	91	21

Clugston farm wells

ID	DATE	COND	pH	ALK mg/l	NH3-N mg/l	TKN mg/l	NO23-N mg/l	Phos mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l
C-100	870716	160	6.7	62	0.02	<0.2	0.10	0.19	7.81	7.75	9.51	2.42	6	12
C-100	870730		6.6	58	0.03	<0.2	0.08	0.15	6.94	6.75	7.81	0.87	5	30
C-101	871001	180	7.7	102	0.04	<0.2	0.08	0.03	17.8	9.62	10.8	0.22	3	<10
C-107	871001	140	6.7	58	0.04	<0.2	0.12	0.17	7.07	8.19	6.52	0.7	6	<10

TABLE 14. Chemical analyses of ground water from domestic wells in the Enterline area

ID	DATE	COND	pH	ALK mg/l	DISS. SOLID mg/l	NO2-N mg/l	NO3-N mg/l	HARD mg/l	CA mg/l	MG mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l
D-100	880720	168	6.6	40	124	0.004	4.20	54	9.97	7.04	6.40	0.84	6	<10
D-101	880720	253	6.6	40	208	0.004	6.00	81	17.9	13.5	7.89	1.69	9	<10
D-102	880720	80	6.6	32	84	<0.004	0.58	29	4.95	3.89	5.39	0.68	<1	<10
D-103	880720	100	6.9	52	160	0.004	0.56	31	4.24	5.42	5.96	0.88	<1	<10
D-104	880720	160	6.8	56	144	0.032	0.39	59	16.5	7.04	5.33	0.62	6	10
D-105	880720	88	6.2	10	62	0.004	1.92	32	6.72	3.39	2.49	1.42	3	<10
D-106	880720	126	6.7	48	148	<0.004	1.60	43	9.06	6.39	6.41	0.98	3	<10
D-107 &108	880720	186	6.8	50	196	<0.004	3.60	65	13.2	11.0	8.19	0.93	6	<10
D-109	880720	135	6.4	32	156	0.004	15.8	41	6.17	6.51	7.27	1.22	6	18
D-110	880726	135	6.2	22	256	<0.004	7.70	44	8.00	6.16	6.40	1.08	8	<10
D-111	880726	160	6.4	38	308	<0.004	5.72	56	10.3	6.99	6.43	1.54	8	<10

ID	DATE	F mg/l	Al ug/l	As ug/l	Ba ug/l	Cd ug/l	Cr ug/l	Fe ug/l	Pb ug/l	Mn ug/l	Ni ug/l	Sr ug/l	Zn ug/l
D-101	880720	<0.10	<135	<100	213	<10	<50	17	<50	<10	34	112	<10
D-102	880720	<0.10	<135	<100	27	<10	<50	26	<50	<10	38	18	<10
D-103	880720	<0.10	193	<100	81	<10	<50	174	132	<10	106	39	26
D-104	880720	<0.10	<135	<100	99	<10	<50	177	72	858	73	39	37
D-105	880720	<0.10	260	<100	124	<10	<50	94	94	20	69	36	21
D-106	880720	<0.10	137	<100	96	<10	<50	<10	<50	<10	36	72	<10
D-107 &108	880720	<0.10	<135	<100	88	<10	<50	<10	<50	<10	<25	55	<10
D-109	880720	<0.10	<135	<100	80	<10	<50	71	101	<10	62	40	21
D-110	880726	<0.10	<135	<100	121	<10	<50	228	<50	<10	44	107	23
D-111	880726	<0.10	<135	<100	138	<10	<50	19	64	12	<25	58	<10

TABLE 15. Chemical analyses from well C-1

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
Lower Zone	891025	0.01	0.5	1.03	1.53	0.03	0.5	5.96	6.38	8.24	1.08	3	17
	900124	0.01	0.1	4.36	4.46	0.03	0.5	8.64	8.67	8.92	1.02	5	13
	900130	0.01	0.36	13.3	13.66	0.02	1.2	12.6	11.1	8.39	1.36	6	22
	900322	0.03	0.1	1.21	1.31	0.03	0.5	6.99	6.17	6.95	0.94	3	11
	900418	0.01	0.1	10.9	11	0.03	1	11.8	9.46	7.18	1.46	6	16
	900523	0.02	0.1	10.7	10.8	0.03	1	10.7	9.33	8.5	2.89	6	22
	9dd0619	0.03	0.2	13.8	14	0.03	1.4	15.5	10.5	6.95	1.77	10	21
	900717	0.01	0.1	2.86	2.96	0.03	1	7.63	6.35	6.79	1.23	4	33
	900829	0.03	0.1	9.68	9.78	0.02	1	13.1	11.6	8.27	1.41	7	23
	900920	0.03	0.1	1.89	1.99	0.03	0.5	7.53	6.57	7.43	1.13	3	22
	901025	0.01	1.54	18.6	20.14	0.02	1.7	13.8	9.66	4.97	2.68	10	24
	901119	0.02	0.28	12.5	12.78	0.03	1.4				1.87	10	5
Upper Zone	891025	0.01	0.5	10.6	11.1	0.13	1.8	9.64	9.53	7.45	1.72	8	28
	900124	0.01	0.1	13.6	13.7	0.05	1.5	14.6	10.7	5.66	2.33	8	23
	900130	0.01	0.38	18.9	19.28	0.03	1.6	20.2	9.42	4.42	2.07	8	25
	900220	0.01	0.1	19.1	19.2	0.02	2.2	17.7	11.9	4.98	1.86	8	24
	900322	0.01	0.25	9.44	9.69	0.03	1.3	11.4	7.35	5.31	1.47	6	15
	900418	0.01	0.38	10.2	10.58	0.03	0.5	12.1	8.24	6.2	1.57	6	16
	900523	0.02	0.29	11.4	11.69	0.03	2.9	13.3	8.04	4.19	3.54	8	24
	900619	0.05	0.51	14	14.51	0.03	1.8	16.8	9.17	6.01	1.98	10	21
	900717	0.02	0.2	15	15.2	0.03	1.4	14.6	8.85	4.72	2.07	9	33

TABLE 15. Chemical analyses from well C-1 (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
Upper Zone	900829	0.03	0.36	16.9	17.26	0.02	2.7	20.1	13.1	5.05	2.26	10	25
	900920	0.03	0.34	4.75	5.09	0.03	1.5	9.21	7.23	6.81	1.34	4	23
	901025	0.01	1.41	20.1	21.51	0.03	1.7	16.4	7.7	3.16	3.34	10	21
	901119	0.02	0.35	14.8	15.15	0.05	1.5				2.57	11	5

	DATE	NO23-N
Difference Upper-Lower	891025	9.57
	900124	9.24
	900130	5.6
	900220	4.58
	900322	8.23
	900418	-0.7
	900523	0.7
	900619	0.2
	900717	12.14
	900829	7.22
	900920	2.86
	901025	1.5
	901119	2.3

TABLE 16. Summary of chemical analyses from well C-1

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.02	0.34	8.18	8.36	0.05	1.29	10.60	8.87	7.31	1.69	6.00	19.65
MAXIMUM	OF	0.11	4.71	26.80	26.80	0.23	7.40	23.70	15.90	16.50	3.85	17.00	39.00
MEDIAN	RECORD	0.02	0.21	8.11	7.24	0.03	1.20	8.79	8.57	7.18	1.48	6.00	21.00
MINIMUM		<0.02	<0.20	<0.04	<0.20	0.02	<1.0	4.01	4.56	3.16	0.85	0.50	<10.0
STDEV		0.02	0.61	7.42	7.48	0.04	1.03	4.77	2.22	2.01	0.66	3.67	8.52
AVERAGE	1987	No data available for 1987											
AVERAGE	1988	0.03	0.60	0.06	0.55	0.11	0.56	6.13	8.42	8.64	1.25	2.00	11.18
MAXIMUM		0.06	4.71	0.20	4.73	0.23	1.00	7.25	9.35	10.20	3.00	4.00	27.00
MEDIAN		0.02	<0.20	<0.04	<0.20	0.08	<1.0	6.33	8.41	8.56	1.11	2.00	10.00
MINIMUM		<0.02	<0.20	<0.04	<0.20	0.04	<1.0	4.01	7.44	7.68	0.92	0.50	<10.0
STDEV		0.02	1.54	0.06	1.39	0.06	0.17	0.95	0.51	0.78	0.59	1.07	7.48
AVERAGE	1989	0.03	0.28	3.80	3.82	0.07	1.16	7.25	8.18	8.59	1.28	3.74	16.21
MAXIMUM		0.11	0.50	11.91	11.96	0.14	4.10	11.30	11.40	13.00	1.84	8.00	28.00
MEDIAN		0.02	0.21	1.14	1.53	0.06	<1.0	6.31	7.74	8.24	1.23	3.00	18.00
MINIMUM		<0.02	<0.20	<0.04	<0.20	0.03	<1.0	4.24	6.28	5.66	0.85	2.00	<10.0
STDEV		0.03	0.20	4.55	4.53	0.04	0.99	2.03	1.57	1.43	0.28	1.97	6.21
AVERAGE	1990	0.02	0.32	12.37	12.66	0.03	1.37	13.09	9.50	6.32	1.92	7.09	21.78
MAXIMUM		0.05	1.54	20.10	21.51	0.05	2.90	20.20	13.10	8.92	3.85	11.00	39.00
MEDIAN		<0.02	0.28	13.80	13.91	0.03	1.40	13.20	9.44	6.59	1.81	6.00	23.00
MINIMUM		<0.02	<0.20	0.17	<0.20	0.02	<1.0	6.99	6.17	3.16	0.94	3.00	<10.0
STDEV		0.01	0.34	5.62	5.77	0.01	0.57	3.50	1.92	1.40	0.72	2.19	6.98

TABLE 16. Summary of chemical analyses from well C-1 (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	1991	0.02	0.23	3.71	3.90	0.04	1.12	8.36	6.01	6.02	1.68	5.29	22.57
MAXIMUM		0.03	0.35	11.10	11.41	0.05	1.60	14.00	8.97	6.81	2.60	9.00	28.00
MEDIAN		0.02	0.25	2.38	2.48	0.03	1.20	7.44	5.73	6.01	1.62	5.00	23.00
MINIMUM		<0.02	<0.20	0.88	1.09	0.02	<1.0	6.76	4.56	5.40	1.11	4.00	12.00
STDEV		0.01	0.11	3.55	3.61	0.01	0.36	2.57	1.38	0.47	0.49	1.80	5.32
AVERAGE	1992	0.03	0.29	12.98	13.17	0.03	3.10	15.26	9.86	7.24	2.27	12.00	31.83
MAXIMUM		0.04	0.34	17.10	17.40	0.04	7.40	20.80	12.00	16.50	2.54	14.00	38.00
MEDIAN		0.03	0.30	13.95	14.23	0.03	1.80	14.60	10.08	5.83	2.30	12.50	32.50
MINIMUM		0.02	0.21	2.77	3.07	0.02	1.40	8.34	5.75	4.62	1.99	8.00	24.00
STDEV		0.01	0.05	5.32	5.27	0.01	2.88	4.29	2.19	4.58	0.19	2.10	5.15

TABLE 17. Summary of chemical analyses from well C-2

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.02	0.11	0.04	0.12	0.13	0.74	10.14	7.54	9.50	0.63	1.35	<10.0
MAXIMUM	OF	0.06	0.24	0.22	0.32	0.18	2.10	10.90	8.24	11.20	0.77	2.00	18.00
MEDIAN	RECORD	0.02	0.10	0.02	0.12	0.13	0.50	10.25	7.54	9.68	0.63	1.50	<10.0
MINIMUM		<0.02	<0.20	<0.04	<0.04	0.08	<1.0	9.03	6.60	7.27	0.50	0.50	<10.0
STDEV		0.01	0.03	0.05	0.06	0.03	0.49	0.48	0.33	0.88	0.07	0.68	4.90
	1987	No data available for 1987											
AVERAGE	1988	0.02	<0.20	0.03	0.11	0.13	0.57	10.16	7.60	8.89	0.64	1.55	10.45
MAXIMUM		0.05	<0.20	0.04	0.14	0.16	1.10	10.90	8.24	10.10	0.76	2.00	17.00
MEDIAN		0.02	<0.20	<0.04	0.12	0.13	<1.0	10.30	7.58	8.73	0.62	2.00	11.00
MINIMUM		<0.02	<0.20	<0.04	<0.04	0.10	<1.0	9.03	6.60	7.27	0.58	1.00	<10.0
STDEV		0.01	0.00	0.01	0.04	0.02	0.20	0.56	0.45	0.88	0.06	0.52	5.52
AVERAGE	1989	0.03	0.12	0.05	0.13	0.13	0.91	10.12	7.48	10.02	0.63	1.19	<10.0
MAXIMUM		0.06	0.24	0.22	0.32	0.18	2.10	10.90	7.80	11.20	0.77	2.00	18.00
MEDIAN		0.02	<0.20	<0.04	0.12	0.13	0.50	10.20	7.52	10.00	0.63	0.50	<10.0
MINIMUM		<0.02	<0.20	<0.04	<0.04	0.08	0.50	9.37	7.23	9.46	0.50	0.50	<10.0
STDEV		0.02	0.05	0.06	0.08	0.03	0.64	0.43	0.19	0.46	0.08	0.78	4.31

TABLE 18. Summary of chemical analyses from well C-3

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.03	0.14	0.32	0.43	0.07	0.88	2.77	6.69	7.77	1.35	2.67	8.43
MAXIMUM	OF	0.09	0.50	1.85	2.35	0.30	3.50	3.52	10.10	9.13	5.08	4.00	24.00
MEDIAN	RECORD	0.02	<0.20	0.13	0.23	0.05	<1.0	2.70	6.34	7.79	1.10	3.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	0.09	0.03	<1.0	2.00	5.03	6.08	0.71	1.00	<10.0
STDEV		0.02	0.11	0.47	0.55	0.07	0.79	0.38	1.07	0.86	0.97	0.73	5.53
	1987	No data available for 1987											
AVERAGE	1988	0.03	<0.20	0.12	0.20	0.09	0.66	2.82	7.20	7.65	1.67	2.33	8.22
MAXIMUM		0.04	<0.20	0.18	0.28	0.30	1.60	3.42	10.10	9.13	5.08	3.00	18.00
MEDIAN		0.03	<0.20	0.12	0.20	0.06	<1.0	2.70	6.72	7.76	1.12	2.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	0.10	0.04	<1.0	2.50	6.24	6.79	0.96	2.00	<10.0
STDEV		0.01	0.00	0.05	0.06	0.09	0.42	0.31	1.26	0.78	1.36	0.50	5.07
AVERAGE	1989	0.03	0.28	0.78	0.97	0.06	1.58	3.04	6.79	7.78	1.42	2.83	9.00
MAXIMUM		0.06	0.50	1.85	2.35	0.11	3.50	3.52	7.60	8.99	2.46	4.00	15.00
MEDIAN		0.03	0.26	0.76	0.82	0.04	1.15	3.09	7.00	7.67	1.28	3.00	8.50
MINIMUM		<0.02	<0.20	0.09	0.09	0.03	<1.0	2.52	5.88	6.40	0.96	1.00	<10.0
STDEV		0.02	0.17	0.70	0.84	0.04	1.33	0.37	0.65	0.95	0.54	0.98	4.52
AVERAGE	1990	0.03	<0.20	0.18	0.26	0.05	0.64	2.45	5.82	7.93	0.82	3.00	8.17
MAXIMUM		0.09	<0.20	0.46	0.56	0.09	1.20	2.72	6.33	8.78	1.12	4.00	24.00
MEDIAN		<0.02	<0.20	0.16	0.23	0.04	<1.0	2.49	5.86	8.39	0.77	3.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	0.12	0.03	<1.0	2.00	5.03	6.08	0.71	2.00	<10.0
STDEV		0.04	0.00	0.16	0.16	0.02	0.31	0.26	0.51	1.02	0.15	0.63	7.76

TABLE 19. Summary of chemical analyses from well C-4

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.05	0.34	0.06	0.31	0.05	0.94	9.24	7.63	10.37	1.08	2.00	11.53
MAXIMUM	OF	0.35	4.93	0.57	4.95	0.15	2.60	27.50	10.40	12.40	3.12	3.00	68.00
MEDIAN	RECORD	0.04	0.10	0.02	0.13	0.04	0.50	8.80	7.63	10.50	1.03	2.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	<0.04	0.02	<1.0	6.95	6.35	8.14	0.10	0.50	<10.0
STDEV		0.06	0.96	0.10	0.83	0.03	0.60	3.33	0.72	1.01	0.50	0.72	11.93
	1987	No data available for 1987											
AVERAGE	1988	0.04	0.72	0.03	0.61	0.06	0.85	8.26	7.93	10.46	1.47	2.30	12.10
MAXIMUM		0.06	4.93	0.08	4.95	0.15	1.40	9.84	10.40	12.10	3.12	3.00	26.00
MEDIAN		0.04	<0.20	<0.04	0.12	0.05	<1.0	8.22	7.73	10.60	1.22	2.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	<0.04	0.02	<1.0	6.95	6.63	9.16	0.75	2.00	<10.0
STDEV		0.02	1.70	0.02	1.53	0.04	0.39	1.02	1.05	1.18	0.67	0.48	8.08
AVERAGE	1989	0.04	0.17	0.08	0.20	0.06	0.96	10.19	7.58	10.66	1.04	1.64	9.07
MAXIMUM		0.06	0.50	0.57	0.57	0.11	2.60	27.50	7.94	12.40	1.37	3.00	22.00
MEDIAN		0.04	<0.20	<0.04	0.14	0.06	<1.0	8.92	7.65	10.50	1.03	2.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	<0.04	0.02	<1.0	7.64	6.35	8.67	0.77	0.50	<10.0
STDEV		0.02	0.15	0.15	0.17	0.03	0.78	5.02	0.37	0.91	0.21	0.79	6.34
AVERAGE	1990	0.03	0.11	0.12	0.21	0.03	1.25	8.45	7.07	10.38	0.73	2.60	<10.0
MAXIMUM		0.05	0.22	0.20	0.35	0.03	2.00	9.00	7.28	10.80	0.89	3.00	<10.0
MEDIAN		0.03	<0.20	0.11	0.21	0.03	1.25	8.65	7.07	10.60	0.75	3.00	<10.0
MINIMUM		<0.02	<0.20	0.07	0.08	0.02	<1.0	7.90	6.89	9.52	0.61	2.00	<10.0
STDEV		0.02	0.09	0.05	0.12	0.01	0.62	0.47	0.14	0.52	0.11	0.55	0.00
	1991	One sample collected on 5-21-91											
		0.02	0.20	<0.04	0.22	0.03	1.20	8.49	6.75	9.31	1.34	2.00	68.00
	1992	One sample collected on 5-13-92											
		0.04	<0.20	<0.04	0.12	0.06	<1.0	9.22	7.84	8.14	0.99	2.00	14.00
	1993	One sample collected on 2-4-93											
		0.35	0.39	<0.04	0.41	0.05	<1.0	10.10	8.76	9.47	0.10	2.00	<10.0

TABLE 20. Summary of chemical analyses from well C-5

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.09	0.42	12.86	13.19	0.06	1.10	11.58	8.42	7.56	1.55	9.04	10.07
MAXIMUM	OF	0.88	6.17	20.60	20.70	0.15	8.50	15.90	10.80	14.80	7.13	13.00	27.00
MEDIAN	RECORD	0.05	<0.20	12.70	12.99	0.05	<1.00	11.70	8.30	7.44	1.34	9.00	<10.0
MINIMUM		<0.02	<0.20	8.14	8.24	0.03	<1.00	7.55	5.73	5.07	0.90	6.00	<10.0
STDEV		0.14	0.97	2.37	2.52	0.03	1.44	1.68	1.08	1.32	0.90	1.39	6.32
	1987	No data available for 1987											
AVERAGE	1988	0.20	0.75	12.04	12.68	0.06	0.95	10.81	8.06	6.94	1.38	9.00	10.46
MAXIMUM		0.88	6.17	15.40	19.17	0.14	3.50	12.40	9.32	10.00	3.03	11.00	20.00
MEDIAN		0.09	<0.20	12.70	12.99	0.05	<1.00	11.60	8.53	6.79	1.16	9.00	10.00
MINIMUM		0.03	<0.20	8.14	8.24	0.03	<1.00	7.55	5.73	5.07	0.92	6.00	<10.0
STDEV		0.25	1.81	2.07	2.85	0.03	1.02	1.47	1.01	1.21	0.57	1.35	5.21
AVERAGE	1989	0.08	0.52	11.77	12.15	0.06	1.48	10.69	7.84	7.64	1.28	8.47	7.53
MAXIMUM		0.39	2.70	13.10	15.30	0.10	3.70	11.90	8.64	8.62	1.88	11.00	16.00
MEDIAN		0.05	<0.20	12.10	12.55	0.06	1.10	10.70	7.81	7.61	1.21	8.00	<10.0
MINIMUM		<0.02	<0.20	9.44	9.54	0.04	<1.00	9.64	7.07	6.28	1.04	6.00	<10.0
STDEV		0.11	0.77	1.21	1.57	0.02	1.24	0.76	0.43	0.55	0.24	1.25	4.49
AVERAGE	1990	0.15	6.57	12.10	6.60	0.42	6.56	9.90	7.91	4.68	5.23	8.71	8.79
MAXIMUM		0.11	0.59	15.50	15.87	0.15	2.30	15.90	10.60	9.12	7.13	11.00	24.00
MEDIAN		0.04	0.20	11.90	12.10	0.04	<1.00	11.60	8.25	7.43	1.14	8.00	<10.0
MINIMUM		<0.02	<0.20	8.95	9.05	0.03	<1.00	7.91	6.04	5.96	0.90	8.00	<10.0
STDEV		0.03	0.18	1.69	1.71	0.04	0.57	1.94	1.23	0.97	1.68	1.01	6.90
AVERAGE	1991	0.04	0.18	14.16	14.31	0.07	<1.00	12.61	9.03	7.53	1.82	9.43	15.71
MAXIMUM		0.06	0.30	15.50	15.60	0.08	<1.00	14.00	9.99	7.99	2.11	10.00	27.00
MEDIAN		0.05	<0.20	14.50	14.50	0.07	<1.00	12.60	9.06	7.46	1.89	10.00	15.00
MINIMUM		0.02	<0.20	12.80	12.90	0.04	<1.00	12.00	8.11	7.09	1.27	8.00	<10.0
STDEV		0.02	0.09	0.99	0.95	0.02	0.00	0.73	0.66	0.33	0.33	0.52	7.36

TABLE 20. Summary of chemical analyses from well C-5 (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	1992	0.04	0.19	15.92	16.04	0.05	2.50	13.28	9.47	8.29	1.64	9.67	11.00
MAXIMUM		0.05	0.33	20.60	20.70	0.06	8.50	14.50	9.76	14.80	1.89	11.00	20.00
MEDIAN		0.05	<0.20	15.20	15.37	0.05	<1.00	13.50	9.55	7.33	1.71	10.00	<10.0
MINIMUM		0.02	<0.20	14.30	14.40	0.05	<1.00	12.00	9.05	6.33	1.33	8.00	<10.0
STDEV		0.01	0.11	2.37	2.36	0.00	4.00	1.02	0.28	3.23	0.20	1.03	6.96
	1993	One sample collected on 2-3-93											
		0.06	<0.20	18.50	18.60	0.05	<1.00	14.80	10.70	8.62	1.41	13.00	<10.0

TABLE 21. Summary of chemical analyses from well H-1

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.11	0.59	4.13	4.61	0.26	3.00	8.14	7.09	6.37	2.03	4.12	14.38
MAXIMUM	OF	0.96	3.46	9.89	9.89	3.12	9.70	17.20	20.80	8.16	26.00	17.00	54.00
MEDIAN	RECORD	0.06	0.29	3.98	4.38	0.05	2.75	7.82	6.39	6.42	1.00	4.00	11.50
MINIMUM		<0.02	<0.20	1.90	2.18	0.01	<1.00	0.01	4.57	4.10	0.69	3.00	<10.0
STDEV		0.17	0.93	1.30	1.49	0.71	2.18	2.45	3.24	0.67	4.05	2.35	12.16
	1987	No data for 1987											
AVERAGE	1988	0.26	0.64	3.10	3.64	0.44	3.88	8.36	7.55	6.17	3.98	5.17	20.08
MAXIMUM		0.96	3.32	4.39	7.04	3.12	9.70	17.20	20.40	6.97	26.00	17.00	51.00
MEDIAN		0.16	0.30	3.45	3.61	0.06	3.50	7.89	6.62	6.46	1.10	3.50	18.50
MINIMUM		0.06	<0.20	1.90	2.18	0.02	<1.00	5.34	4.57	4.10	0.82	3.00	<10.0
STDEV		0.27	0.98	0.81	1.25	0.96	2.81	2.95	4.12	0.81	7.15	4.04	12.76
AVERAGE	1989	0.05	0.72	4.16	4.68	0.10	3.69	7.25	6.52	6.57	1.41	3.36	10.86
MAXIMUM		0.17	3.37	5.57	7.00	0.48	5.90	9.71	11.80	7.29	7.51	4.00	31.00
MEDIAN		0.04	0.37	3.99	4.41	0.06	4.15	7.55	5.97	6.48	0.92	3.00	<10.0
MINIMUM		<0.02	<0.20	3.63	3.70	0.01	<1.00	0.01	5.50	5.48	0.79	3.00	<10.0
STDEV		0.05	1.03	0.57	0.94	0.14	1.82	2.23	1.60	0.50	1.76	0.50	8.36
AVERAGE	1990	0.03	0.49	5.00	5.42	0.30	1.80	8.95	7.58	6.45	1.12	4.00	15.08
MAXIMUM		0.06	3.46	9.89	9.89	2.88	4.80	15.80	20.80	8.16	2.20	8.00	54.00
MEDIAN		0.03	<0.20	4.36	4.75	0.04	1.30	8.66	6.40	6.47	0.83	4.00	10.00
MINIMUM		<0.02	<0.20	3.86	3.86	0.02	<1.00	6.99	5.60	5.64	0.69	3.00	<10.0
STDEV		0.02	0.99	1.71	1.88	0.86	1.57	2.26	4.03	0.68	0.51	1.35	14.51
AVERAGE	1991	0.06	0.27	4.35	4.63	0.07	2.20	7.96	5.85	5.93	0.99	4.00	<10.0
MAXIMUM		0.08	0.35	4.84	5.06	0.08	2.80	9.57	6.97	6.32	1.08	4.00	<10.0
MEDIAN		0.06	0.25	4.11	4.46	0.07	2.20	7.64	5.39	6.17	1.04	4.00	<10.0
MINIMUM		0.05	0.22	4.11	4.36	0.05	1.60	6.66	5.20	5.30	0.86	4.00	<10.0
STDEV		0.02	0.07	0.42	0.38	0.02	0.60	1.48	0.97	0.55	0.12	0.00	0.00
	1992	No data for 1992											

TABLE 22. Summary of chemical analyses from well H-2

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.04	0.50	11.52	11.94	0.07	0.98	8.85	6.61	3.55	1.74	4.58	10.79
MAXIMUM	OF	0.11	7.96	19.80	21.46	0.28	4.70	16.60	8.99	8.09	3.48	6.00	32.00
MEDIAN	RECORD	0.04	0.20	11.50	11.60	0.05	0.50	8.44	6.49	3.43	1.65	4.50	7.50
MINIMUM		<0.02	<0.20	5.54	5.64	0.03	<1.00	3.76	3.51	2.28	0.91	3.00	<10.0
STDEV		0.03	1.35	2.77	3.16	0.05	0.96	2.28	1.19	0.83	0.48	0.77	6.81
AVERAGE	1988	0.04	0.15	9.91	10.04	0.10	0.73	7.79	6.06	3.36	1.75	4.50	11.58
MAXIMUM		0.06	0.34	11.90	11.91	0.28	1.70	10.50	7.18	4.29	2.30	6.00	32.00
MEDIAN		0.04	0.10	10.38	10.45	0.08	<1.00	7.97	6.28	3.38	1.72	4.00	7.50
MINIMUM		<0.02	<0.20	7.32	7.53	0.04	<1.00	4.42	3.51	2.28	1.27	4.00	<10.0
STDEV		0.02	0.10	1.27	1.24	0.07	0.41	1.52	0.90	0.50	0.37	0.67	8.63
AVERAGE	1989	0.04	0.89	12.82	13.52	0.07	1.10	9.03	7.11	3.76	1.93	4.64	9.00
MAXIMUM		0.11	7.96	19.80	21.46	0.18	4.20	13.00	8.99	4.45	3.48	6.00	16.00
MEDIAN		0.04	0.21	13.90	14.41	0.06	<1.00	10.15	7.53	3.81	1.85	5.00	8.00
MINIMUM		<0.02	<0.20	5.54	5.64	0.05	<1.00	3.76	4.46	2.74	1.20	3.00	<10.0
STDEV		0.04	2.35	4.06	4.64	0.04	1.09	2.78	1.56	0.52	0.58	0.84	4.28
AVERAGE	1990	0.03	0.56	12.13	12.61	0.05	1.01	9.41	6.96	3.33	1.69	4.71	11.21
MAXIMUM		0.07	3.86	14.50	16.16	0.10	2.40	12.00	8.46	4.29	2.66	6.00	21.00
MEDIAN		0.02	0.28	12.35	12.77	0.05	<1.00	8.98	6.94	3.29	1.58	4.50	8.50
MINIMUM		<0.02	<0.20	8.23	8.43	0.03	<1.00	6.76	5.53	2.62	0.94	4.00	<10.0
STDEV		0.02	1.05	1.81	2.10	0.02	0.75	1.62	0.92	0.43	0.50	0.83	7.05
AVERAGE	1991	0.05	0.33	11.02	11.30	0.05	<1.00	8.25	6.23	3.35	1.51	4.50	9.67
MAXIMUM		0.10	0.86	12.30	12.40	0.08	<1.00	8.97	6.86	3.63	2.03	5.00	19.00
MEDIAN		0.04	0.25	10.85	11.45	0.04	<1.00	8.27	6.20	3.40	1.52	4.50	<10.0
MINIMUM		0.02	<0.20	9.44	9.54	0.03	<1.00	7.78	5.47	2.90	0.91	4.00	<10.0
STDEV		0.03	0.31	1.13	1.07	0.02	0.00	0.44	0.48	0.25	0.38	0.55	7.23
	One sample collected on 2/11/92												
		0.02	<0.20	11.40	11.50	0.04	4.70	16.60	4.76	8.09	1.53	5.00	22.00
	One sample collected on 2/4/93												
		0.07	<0.20	7.26	7.36	0.06	<1.00	7.09	5.50	2.60	1.33	3.00	16.00

TABLE 23. Summary of chemical analyses from well H-3

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.03	0.21	6.60	6.77	0.08	0.76	3.95	4.59	4.10	1.10	4.08	7.25
MAXIMUM	OF	0.07	1.02	10.40	10.50	0.26	4.00	7.86	7.06	5.08	1.93	5.00	21.00
MEDIAN	RECORD	0.02	0.10	7.02	7.14	0.07	<1.00	3.74	4.31	4.13	0.99	4.00	<10.0
MINIMUM		<0.02	<0.20	4.62	4.72	0.04	<1.00	2.92	3.44	3.15	0.72	3.00	<10.0
STDEV		0.02	0.19	1.56	1.57	0.04	0.69	0.90	0.77	0.43	0.29	0.49	5.17
	1987	No data available for 1987											
AVERAGE	1988	0.03	0.15	5.36	5.48	0.10	0.67	3.59	4.38	3.85	1.08	4.00	7.67
MAXIMUM		0.07	0.46	7.04	7.14	0.26	1.60	5.12	7.06	4.34	1.55	5.00	21.00
MEDIAN		0.02	<0.20	5.17	5.36	0.09	<1.00	3.48	4.05	3.85	1.00	4.00	<10.0
MINIMUM		<0.02	<0.20	4.62	4.72	0.06	<1.00	2.96	3.52	3.30	0.78	3.00	<10.0
STDEV		0.02	0.12	0.63	0.63	0.06	0.38	0.60	0.98	0.30	0.21	0.43	6.23
AVERAGE	1989	0.02	0.30	6.52	6.75	0.07	0.65	4.18	4.59	4.14	1.13	3.92	6.62
MAXIMUM		0.07	1.02	8.95	9.33	0.12	1.50	7.86	6.45	4.74	1.65	5.00	13.00
MEDIAN		<0.02	0.28	5.57	6.10	0.08	<1.00	3.69	4.30	4.12	1.03	4.00	<10.0
MINIMUM		<0.02	<0.20	4.88	4.98	0.04	<1.00	2.92	3.44	3.15	0.75	3.00	<10.0
STDEV		0.02	0.28	1.50	1.53	0.02	0.34	1.34	0.82	0.47	0.30	0.49	3.15
AVERAGE	1990	0.03	0.17	8.07	8.21	0.06	0.98	4.08	4.83	4.32	1.09	4.36	7.55
MAXIMUM		0.05	0.41	10.40	10.50	0.08	4.00	4.76	5.44	5.08	1.93	5.00	19.00
MEDIAN		0.03	<0.20	7.74	7.84	0.06	<1.00	4.05	4.88	4.31	0.91	4.00	<10.0
MINIMUM		<0.02	<0.20	7.26	7.26	0.05	<1.00	3.42	3.92	3.53	0.72	4.00	<10.0
STDEV		0.02	0.11	1.18	1.14	0.01	1.16	0.37	0.41	0.41	0.37	0.50	4.74
	1991	One sample collected on 4-10-91											
		0.02	<0.20	7.26	7.36	0.07	<1.00	3.93	4.49	4.39	0.94	4.00	21.00

TABLE 24. Summary of chemical analyses from the Halifax field drain

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.06	0.47	22.40	22.85	0.09	1.78	21.61	12.43	5.17	2.86	16.53	16.65
MAXIMUM	OF	7.81	40.80	42.50	66.40	4.95	114.00	56.20	26.80	75.40	14.69	125.00	52.00
MEDIAN	RECORD	0.02	0.22	21.50	21.78	0.03	1.20	19.10	12.30	4.72	2.41	16.00	17.00
MINIMUM		<0.02	<0.20	1.69	1.93	<0.01	<1.00	4.18	0.06	<0.20	0.37	1.00	<10.0
STDEV		0.45	2.43	4.47	5.20	0.41	6.43	8.29	2.30	5.09	1.50	6.84	7.26
AVERAGE	1987	0.23	1.32	26.21	27.34	0.16	3.31	30.95	13.66	4.56	4.31	19.10	12.96
MAXIMUM		7.81	40.80	33.20	66.40	4.95	114.00	56.20	18.80	10.30	14.69	46.00	45.00
MEDIAN		0.08	0.43	26.50	27.21	0.08	1.20	25.95	13.70	4.37	3.98	19.00	12.00
MINIMUM		<0.02	<0.20	16.10	16.90	<0.01	<1.00	13.40	6.32	3.27	1.98	10.00	<10.0
STDEV		0.95	5.30	3.51	5.92	0.59	13.73	12.13	1.97	0.93	2.08	3.80	7.57
AVERAGE	1988	0.02	0.17	19.21	19.39	0.21	1.49	18.08	12.08	4.06	2.69	16.06	17.19
MAXIMUM		0.22	0.78	22.80	23.39	4.07	7.20	23.60	17.60	5.79	8.36	23.00	52.00
MEDIAN		<0.02	<0.20	19.40	19.50	0.03	1.05	17.95	12.00	4.03	2.34	16.00	15.00
MINIMUM		<0.02	<0.20	13.40	13.50	<0.01	<1.00	8.90	7.28	2.44	1.90	1.00	<10.0
STDEV		0.03	0.16	2.05	2.07	0.74	1.53	2.28	1.58	0.84	1.09	2.96	8.92
AVERAGE	1989	<0.02	0.20	21.60	21.80	0.04	1.45	19.33	12.43	6.48	2.70	18.39	15.23
MAXIMUM		0.07	0.64	26.30	26.58	0.19	5.00	55.50	26.80	75.40	8.08	125.00	31.00
MEDIAN		<0.02	<0.20	21.50	21.75	0.03	1.30	18.95	12.20	4.72	2.48	16.50	15.00
MINIMUM		<0.02	<0.20	16.00	16.10	<0.01	<1.00	11.50	7.97	3.31	1.94	12.00	<10.0
STDEV		0.01	0.14	1.79	1.81	0.03	0.80	4.79	2.05	10.63	1.01	13.05	5.99
AVERAGE	1990	<0.02	0.51	20.93	21.44	0.02	1.21	19.03	11.74	4.97	2.19	14.83	20.08
MAXIMUM		0.05	12.50	26.30	36.70	0.05	2.10	23.20	14.70	6.14	5.95	17.00	39.00
MEDIAN		<0.02	0.25	21.15	21.32	0.02	1.20	18.85	11.90	5.03	2.15	15.00	21.00
MINIMUM		<0.02	<0.20	13.60	13.89	<0.01	<1.00	13.60	0.07	3.39	1.17	13.00	11.00
STDEV		0.01	1.68	2.31	3.12	0.01	0.31	2.12	2.01	0.61	0.65	0.69	5.34

TABLE 24. Summary of chemical analyses from the Halifax field drain (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	1991	0.02	0.25	20.15	20.40	0.02	1.13	17.46	11.06	5.04	2.22	12.77	18.88
MAXIMUM		0.11	0.93	26.30	26.40	0.09	2.90	20.30	14.90	5.69	9.40	15.00	26.00
MEDIAN		0.02	0.23	20.20	20.42	0.02	1.10	18.05	10.95	5.10	2.05	13.00	21.00
MINIMUM		<0.02	<0.20	6.78	7.12	<0.01	<1.00	4.18	6.59	4.22	0.37	7.00	<10.0
STDEV		0.02	0.19	3.27	3.26	0.02	0.43	3.27	1.58	0.35	1.46	1.43	6.35
AVERAGE	1992	0.03	0.25	23.29	23.54	0.03	1.43	19.98	12.51	5.34	2.31	14.63	18.00
MAXIMUM		0.09	1.75	42.50	42.91	0.23	6.70	49.10	17.20	7.39	3.94	18.00	29.00
MEDIAN		0.02	0.22	21.50	22.40	0.02	1.20	18.60	12.20	5.20	2.28	15.00	20.00
MINIMUM		<0.02	<0.20	1.69	1.93	<0.01	1.00	10.40	2.28	<0.20	0.50	11.00	<10.0
STDEV		0.02	0.27	6.94	6.95	0.04	0.89	6.13	2.71	1.24	0.51	1.91	6.51
AVERAGE	1993	0.02	0.29	33.35	33.64	0.02	1.27	25.75	13.64	6.90	2.42	16.33	19.17
MAXIMUM		0.02	0.48	36.50	36.80	0.02	1.90	28.20	17.60	7.89	2.64	18.00	22.00
MEDIAN		0.02	0.30	32.80	33.09	0.02	1.15	25.65	16.10	6.75	2.41	16.00	21.00
MINIMUM		<0.02	<0.20	31.40	31.64	<0.01	1.00	23.90	0.06	6.45	2.14	15.00	14.00
STDEV		0.01	0.12	1.99	1.97	0.01	0.33	1.59	6.69	0.54	0.20	1.03	3.66

TABLE 25. Summary of chemical analyses from the Halifax spring

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	<0.02	<0.20	21.80	21.99	0.03	<1.00	16.99	12.46	4.97	3.75	16.12	11.06
MAXIMUM	OF	0.34	1.51	35.10	35.86	0.51	5.60	24.00	20.80	61.90	188.00	106.00	78.00
MEDIAN	RECORD	<0.02	<0.20	21.52	21.85	0.02	<1.00	17.00	12.30	4.57	2.78	15.00	<10.0
MINIMUM		<0.02	<0.20	7.09	7.99	<0.01	<1.00	3.55	0.08	1.24	0.25	5.00	<10.0
STDEV		0.02	0.20	3.35	3.35	0.04	0.68	2.39	2.08	4.69	10.94	6.04	8.15
AVERAGE	1987	<0.02	0.23	22.43	22.66	0.03	1.10	15.46	12.36	4.18	3.55	17.97	9.67
MAXIMUM		0.05	1.51	29.80	29.90	0.09	5.60	22.00	16.10	4.70	10.99	38.00	22.00
MEDIAN		<0.02	<0.20	21.92	22.08	0.02	<1.00	15.45	12.40	4.24	3.27	17.00	<10.0
MINIMUM		<0.02	<0.20	17.20	17.30	<0.01	<1.00	12.10	9.76	3.35	2.35	11.00	<10.0
STDEV		0.01	0.29	3.60	3.63	0.02	1.37	2.14	2.01	0.37	1.64	4.91	5.79
AVERAGE	1988	0.02	<0.20	19.03	19.16	0.04	<1.00	16.24	12.23	5.02	3.79	16.35	14.37
MAXIMUM		0.12	0.90	22.30	22.40	0.51	5.50	20.90	20.80	60.60	41.20	48.00	78.00
MEDIAN		<0.02	<0.20	19.40	19.50	0.03	<1.00	16.30	11.70	4.10	2.74	15.00	12.00
MINIMUM		<0.02	<0.20	7.09	7.99	<0.01	<1.00	8.21	0.08	1.78	2.10	14.00	<10.0
STDEV		0.02	0.12	2.31	2.24	0.07	0.80	2.21	3.14	7.53	5.52	4.79	12.87
AVERAGE	1989	<0.02	<0.20	22.09	22.27	0.04	<1.00	17.51	12.81	5.41	3.35	17.98	9.21
MAXIMUM		0.08	0.52	29.10	29.62	0.36	2.80	21.10	16.00	61.90	12.90	106.00	26.00
MEDIAN		<0.02	<0.20	22.30	22.40	0.03	<1.00	17.35	12.75	4.51	3.02	16.00	<10.0
MINIMUM		<0.02	<0.20	10.63	10.73	<0.01	<1.00	13.30	10.30	3.70	2.32	12.00	<10.0
STDEV		0.01	0.11	2.41	2.42	0.05	0.54	1.50	1.32	7.08	1.44	11.21	5.78
AVERAGE	1990	<0.02	0.25	21.42	21.67	0.03	<1.00	17.26	12.24	4.63	6.04	14.91	12.49
MAXIMUM		0.09	1.29	25.00	25.66	0.31	2.60	22.10	15.20	7.74	188.00	21.00	34.00
MEDIAN		<0.02	<0.20	21.80	22.10	0.02	<1.00	17.46	12.40	4.74	2.49	15.00	12.00
MINIMUM		<0.02	<0.20	11.10	12.06	<0.01	<1.00	11.80	4.82	1.72	0.80	5.00	<10.0
STDEV		0.01	0.25	2.18	2.14	0.04	0.45	1.92	1.68	0.86	24.79	1.84	7.74

TABLE 25. Summary of chemical analyses from the Halifax spring (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	1991	0.02	0.24	20.91	21.15	0.02	<1.00	16.52	11.68	5.01	2.58	14.11	10.52
MAXIMUM		0.06	1.32	27.30	27.40	0.10	1.70	22.20	14.80	16.00	3.78	17.00	21.00
MEDIAN		0.02	<0.20	20.90	21.15	0.02	<1.00	16.35	11.35	4.76	2.69	14.00	10.00
MINIMUM		<0.02	<0.20	9.92	10.23	<0.01	<1.00	3.55	9.56	3.58	1.33	12.00	<10.0
STDEV		0.01	0.26	2.84	2.81	0.02	0.35	2.76	1.44	1.77	0.57	1.08	5.86
AVERAGE	1992	0.03	<0.20	24.77	24.94	0.02	<1.00	17.67	12.98	5.05	2.88	15.44	10.02
MAXIMUM		0.34	0.76	35.10	35.86	0.12	4.20	23.80	16.90	7.96	9.66	21.00	23.00
MEDIAN		0.02	<0.20	24.00	24.18	0.02	<1.00	17.85	13.15	4.98	2.72	15.00	<10.0
MINIMUM		<0.02	<0.20	19.60	19.81	<0.01	<1.00	6.27	2.61	1.24	0.25	7.00	<10.0
STDEV		0.05	0.14	3.47	3.50	0.02	0.57	2.97	2.09	0.96	1.13	1.87	6.11
AVERAGE	1993	0.01	<0.20	28.53	28.73	0.02	<1.00	20.63	14.98	5.70	2.84	16.50	<10.0
MAXIMUM		0.02	0.39	30.90	31.29	0.02	1.20	24.00	17.00	6.65	3.48	18.00	<10.0
MEDIAN		<0.02	<0.20	29.55	29.76	0.02	<1.00	20.05	14.40	5.60	2.81	16.50	<10.0
MINIMUM		<0.02	<0.20	23.50	23.51	<0.01	<1.00	18.90	14.00	5.09	2.43	15.00	<10.0
STDEV		0.01	0.15	2.79	2.92	0.01	0.29	1.79	1.27	0.57	0.36	1.05	0.00

TABLE 26. Summary of chemical analyses from the Halifax surface runoff

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.12	1.61	7.21	8.81	0.79	12.98	10.82	6.29	4.19	12.09	10.73	13.67
MAXIMUM	OF	0.49	5.05	23.70	24.71	3.60	38.60	25.80	15.20	66.30	29.50	130.00	38.00
MEDIAN	RECORD	0.09	1.21	5.69	7.04	0.72	10.25	8.37	5.02	1.80	10.81	6.00	14.00
MINIMUM		<0.02	0.30	0.15	0.98	0.03	<1.00	1.55	0.74	0.29	1.33	1.00	<10.0
STDEV		0.09	1.18	7.17	7.14	0.61	10.00	6.92	4.22	11.25	7.66	20.60	7.97
AVERAGE	07-04-89	0.14	3.00	7.05	10.05	1.41	24.93	11.80	6.64	2.44	21.28	7.54	13.77
MAXIMUM	thru	0.25	5.05	21.30	22.36	2.04	38.60	25.80	14.40	5.07	29.50	15.00	21.00
MEDIAN	07-05-89	0.17	2.25	6.29	9.93	1.68	23.70	11.60	6.58	2.84	23.60	8.00	14.00
MINIMUM		0.02	1.06	2.90	4.82	0.60	7.50	6.64	3.81	0.93	10.62	4.00	<10.0
STDEV		0.08	1.50	4.77	4.60	0.57	10.53	5.01	2.77	1.12	7.05	3.07	4.76
AVERAGE	07-13-89	0.08	1.32	3.26	4.58	0.69	15.28	7.24	3.72	6.10	11.66	12.00	7.23
MAXIMUM	thru	0.14	1.83	23.70	24.71	0.88	19.80	24.30	13.90	66.30	14.58	113.00	15.00
MEDIAN	07-14-89	0.07	1.21	1.21	2.46	0.72	15.50	6.08	2.87	0.89	11.44	4.00	<10.0
MINIMUM		0.04	0.93	0.31	1.24	0.13	5.50	4.35	1.84	0.67	5.88	2.00	<10.0
STDEV		0.03	0.31	6.32	6.28	0.19	3.61	5.22	3.14	18.09	2.39	30.36	3.61
AVERAGE	10-18-89	0.12	1.06	4.80	5.87	0.64	5.69	7.81	4.54	2.13	11.25	6.40	10.93
MAXIMUM	thru	0.23	1.97	20.10	20.64	0.87	12.00	23.30	13.70	4.69	20.09	14.00	23.00
MEDIAN	10-21-89	0.12	0.95	0.44	1.39	0.74	3.80	5.00	2.05	0.54	10.17	4.00	<10.0
MINIMUM		<0.02	<0.20	0.50	0.15	0.98	<1.00	0.50	1.55	0.74	0.29	3.51	<10.0
STDEV		0.05	0.40	6.28	6.35	0.25	3.66	6.21	3.91	2.00	5.44	4.34	7.67
AVERAGE	12-31-89	0.48	4.25	10.41	14.66	1.23	31.00	14.30	9.36	2.51	22.35	9.00	34.50
MAXIMUM		0.49	4.40	11.86	16.26	1.38	34.80	16.90	10.80	2.73	26.10	10.00	38.00
MEDIAN		0.48	4.25	10.41	14.66	1.23	31.00	14.30	9.36	2.51	22.35	9.00	34.50
MINIMUM		0.47	4.10	8.95	13.05	1.08	27.20	11.70	7.92	2.28	18.60	8.00	31.00
STDEV		0.01	0.21	2.06	2.27	0.21	5.37	3.68	2.04	0.32	5.30	1.41	4.95

TABLE 26. Summary of chemical analyses from the Halifax surface runoff (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	01-29-90	0.18	1.45	2.18	3.63	0.61	10.25	5.23	4.10	1.15	10.30	6.50	16.50
MAXIMUM		0.24	1.80	2.66	3.76	0.75	11.30	5.59	4.16	1.26	10.50	7.00	17.00
MEDIAN		0.18	1.45	2.18	3.63	0.61	10.25	5.23	4.10	1.15	10.30	6.50	16.50
MINIMUM		0.12	1.10	1.69	3.49	0.47	9.20	4.87	4.04	1.04	10.10	6.00	16.00
STDEV		0.08	0.49	0.69	0.19	0.20	1.48	0.51	0.08	0.16	0.28	0.71	0.71
AVERAGE	12-26-90	0.18	1.19	1.92	3.12	0.55	9.97	5.01	3.21	1.22	6.38	6.33	7.00
MAXIMUM		0.21	1.52	4.60	6.12	0.72	12.20	6.83	4.53	1.48	14.90	10.00	11.00
MEDIAN		0.21	1.04	0.97	1.99	0.47	9.20	4.40	2.75	1.12	2.31	5.00	<10.0
MINIMUM		0.12	1.02	0.20	1.24	0.47	8.50	3.81	2.35	1.05	1.92	4.00	<10.0
STDEV		0.05	0.28	2.35	2.63	0.14	1.97	1.60	1.16	0.23	7.38	3.21	3.46
AVERAGE	07-17-91	0.07	0.79	15.11	15.90	0.25	4.66	17.71	10.36	3.42	3.30	9.56	21.22
MAXIMUM	thru	0.11	1.27	18.60	19.12	0.44	7.90	21.10	12.20	4.14	6.04	11.00	23.00
MEDIAN	07-18-91	0.07	0.66	18.40	18.92	0.21	3.40	20.60	11.90	4.01	2.91	11.00	22.00
MINIMUM		0.04	0.52	7.26	8.41	0.19	3.00	9.97	6.04	1.82	2.42	6.00	15.00
STDEV		0.02	0.33	5.01	4.70	0.09	2.13	4.73	2.59	0.97	1.12	2.24	2.64

TABLE 27. Summary of chemical analyses from the wetland inlet

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.03	0.22	22.74	22.95	0.02	1.09	18.11	12.17	5.16	3.11	14.48	12.97
MAXIMUM	OF	0.18	1.93	35.10	35.39	0.17	22.70	26.10	17.50	10.10	61.30	19.00	31.00
MEDIAN	RECORD	0.02	0.10	21.80	22.10	0.02	1.00	17.70	12.00	4.99	2.51	14.00	12.00
MINIMUM		<0.02	<0.20	7.74	8.23	0.01	<1.00	9.95	1.71	2.68	<0.50	11.00	<10.0
STDEV		0.03	0.26	4.26	4.26	0.02	2.11	3.04	2.10	0.94	5.59	1.41	7.23
AVERAGE	1990	<0.02	0.41	22.78	23.19	0.02	0.80	17.83	12.17	4.33	2.56	14.30	11.90
MAXIMUM		<0.02	1.93	24.20	26.13	0.05	1.20	23.00	14.60	5.38	3.30	15.00	22.00
MEDIAN		<0.02	<0.20	22.85	23.21	0.02	0.75	17.70	12.30	4.14	2.56	14.00	11.00
MINIMUM		<0.02	<0.20	21.20	21.30	0.01	<1.00	14.60	10.10	3.22	1.60	14.00	<10.0
STDEV		0.00	0.59	0.93	1.33	0.01	0.32	2.82	1.51	0.62	0.56	0.48	5.95
AVERAGE	1991	0.03	0.22	20.09	20.31	0.02	0.89	16.95	11.25	5.00	3.62	13.58	13.83
MAXIMUM		0.18	1.15	26.30	26.40	0.07	2.40	22.30	13.90	10.10	61.30	16.00	24.00
MEDIAN		0.02	<0.20	20.30	20.40	0.02	1.00	16.40	11.05	4.94	2.46	14.00	14.50
MINIMUM		<0.02	<0.20	7.74	8.23	0.01	<1.00	13.50	9.41	3.58	0.77	12.00	<10.0
STDEV		0.04	0.22	2.68	2.66	0.01	0.46	1.97	1.17	0.92	8.53	0.85	7.11
AVERAGE	1992	0.02	0.19	23.91	24.09	0.02	0.92	18.51	12.62	5.30	2.57	14.96	12.29
MAXIMUM		0.07	1.24	35.10	35.39	0.17	5.30	25.90	16.80	7.58	3.78	18.00	31.00
MEDIAN		0.02	<0.20	22.80	23.10	0.02	1.00	18.00	12.40	5.22	2.57	15.00	12.00
MINIMUM		<0.02	<0.20	17.20	17.65	0.01	<1.00	9.95	1.71	4.03	<0.50	11.00	<10.0
STDEV		0.01	0.18	4.19	4.18	0.03	0.73	3.27	2.20	0.78	0.50	1.33	7.57
AVERAGE	1993	0.02	0.20	29.40	29.58	0.02	3.36	21.96	14.36	6.03	3.92	16.50	13.44
MAXIMUM		0.05	0.47	34.20	34.48	0.03	22.70	26.10	17.50	7.30	17.00	19.00	24.00
MEDIAN		<0.02	<0.20	29.80	30.04	0.02	1.00	22.40	14.90	6.31	2.46	16.00	13.00
MINIMUM		<0.02	<0.20	23.90	24.00	0.01	<1.00	15.40	5.63	2.68	2.27	15.00	<10.0
STDEV		0.01	0.13	2.84	2.89	0.01	7.26	3.06	3.26	1.25	4.60	1.43	7.73

TABLE 28. Summary of chemical analyses from the wetland outlet

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.03	0.24	21.17	21.41	0.02	2.34	18.18	12.65	5.16	2.98	14.77	20.79
MAXIMUM	OF	0.12	0.92	33.70	34.01	0.13	120.00	25.40	17.10	7.42	10.10	38.00	82.00
MEDIAN	RECORD	0.02	0.21	21.30	21.40	0.02	1.10	17.90	12.50	5.07	2.72	14.00	20.00
MINIMUM		<0.02	<0.20	3.15	3.45	0.01	<1.00	9.50	8.12	2.47	<0.50	9.00	<10.0
STDEV		0.02	0.18	5.79	5.77	0.02	11.34	3.07	1.82	0.83	1.30	2.71	12.27
AVERAGE	1990	0.02	0.24	22.26	22.49	0.02	1.09	18.06	12.49	4.38	2.82	14.33	17.44
MAXIMUM		0.05	0.69	24.20	24.52	0.05	1.30	24.00	15.50	5.52	3.57	15.00	24.00
MEDIAN		<0.02	<0.20	21.30	21.89	0.02	1.00	17.90	12.40	4.19	2.78	14.00	21.00
MINIMUM		<0.02	<0.20	20.10	20.20	0.01	1.00	14.40	10.80	3.27	1.65	14.00	<10.0
STDEV		0.02	0.23	1.53	1.57	0.01	0.14	3.04	1.63	0.63	0.62	0.50	7.26
AVERAGE	1991	0.03	0.26	17.23	17.48	0.02	1.26	17.29	11.90	4.91	3.11	13.52	27.82
MAXIMUM		0.12	0.92	25.40	25.50	0.06	3.10	22.30	17.10	7.42	6.65	16.00	82.00
MEDIAN		0.03	0.21	18.90	19.19	0.02	1.10	17.30	11.75	5.01	2.84	14.00	25.50
MINIMUM		<0.02	<0.20	3.15	3.45	0.01	<1.00	10.30	8.12	2.47	0.96	9.00	<10.0
STDEV		0.02	0.21	5.32	5.32	0.01	0.66	2.32	1.68	0.77	1.31	1.25	15.24
AVERAGE	1992	0.03	0.23	22.88	23.10	0.02	3.72	18.19	12.83	5.30	2.93	15.60	15.98
MAXIMUM		0.12	0.88	33.70	34.01	0.13	120.00	25.40	16.80	6.68	10.10	38.00	34.00
MEDIAN		0.02	0.23	22.50	22.60	0.02	1.10	17.90	12.75	5.38	2.63	15.00	18.00
MINIMUM		<0.02	<0.20	13.60	14.48	0.01	<1.00	9.50	10.10	3.74	<0.50	11.00	<10.0
STDEV		0.02	0.17	4.65	4.62	0.02	16.98	3.25	1.61	0.74	1.48	3.50	7.39
AVERAGE	1993	0.06	0.22	28.70	28.90	0.02	1.19	22.15	15.14	6.24	2.77	16.30	17.90
MAXIMUM		0.12	0.32	33.30	33.59	0.04	1.70	25.30	17.10	7.02	3.21	18.00	27.00
MEDIAN		0.05	0.22	29.80	29.94	0.02	1.10	22.30	14.80	6.32	2.72	16.50	20.00
MINIMUM		<0.02	<0.20	23.70	23.90	0.01	<1.00	19.40	13.30	5.48	2.42	14.00	<10.0
STDEV		0.04	0.08	2.83	2.83	0.01	0.35	2.09	1.18	0.45	0.22	1.16	6.81

TABLE 29. Summary of chemical analyses from the Enterline field drain

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.09	0.40	8.14	8.53	0.14	2.47	10.71	4.19	3.01	3.56	5.81	11.74
MAXIMUM	OF	4.29	4.04	53.00	57.04	1.76	12.20	57.70	15.20	67.20	212.00	125.00	50.00
MEDIAN	RECORD	0.03	0.23	7.50	7.73	0.03	1.10	8.99	3.61	1.43	1.56	4.00	11.00
MINIMUM		<0.02	<0.20	0.50	1.23	0.01	<1.00	4.58	1.74	0.03	0.59	2.00	<10.0
STDEV		0.29	0.45	5.63	5.66	0.29	2.98	6.14	1.99	7.26	13.13	10.08	7.58
AVERAGE	1987	0.11	0.60	6.22	6.77	0.23	4.14	8.57	4.06	3.37	3.90	5.26	11.78
MAXIMUM		0.61	2.00	26.52	26.52	1.65	12.20	17.30	13.90	18.50	27.60	34.00	50.00
MEDIAN		0.07	0.60	7.26	7.36	0.06	2.50	8.32	3.58	1.49	2.12	5.00	10.00
MINIMUM		<0.02	<0.20	0.50	1.28	0.01	<1.00	4.58	2.26	0.10	0.86	3.00	<10.0
STDEV		0.11	0.43	3.78	3.59	0.33	3.74	2.41	1.84	4.74	4.20	3.62	8.47
AVERAGE	1988	0.29	0.41	11.33	11.74	0.21	1.51	14.39	4.62	1.48	3.08	5.56	12.50
MAXIMUM		4.29	4.04	53.00	57.04	1.76	6.60	57.70	12.40	2.88	26.10	25.00	27.00
MEDIAN		0.04	<0.20	8.47	8.79	0.04	1.10	11.65	3.82	1.42	1.51	4.00	13.00
MINIMUM		<0.02	<0.20	6.16	6.44	0.01	<1.00	6.36	2.33	0.84	0.92	3.00	<10.0
STDEV		0.76	0.72	8.91	9.49	0.47	1.38	9.81	2.13	0.43	5.33	4.52	6.63
AVERAGE	1989	0.02	0.23	12.47	12.70	0.04	1.37	15.76	5.11	5.55	2.21	9.90	8.94
MAXIMUM		0.08	2.00	25.40	25.50	0.19	5.90	56.80	14.50	67.20	26.30	125.00	23.00
MEDIAN		<0.02	<0.20	10.20	10.46	0.03	<1.00	12.25	4.48	1.54	1.51	5.00	<10.0
MINIMUM		<0.02	<0.20	0.90	1.23	0.01	<1.00	5.59	1.74	0.25	1.10	2.00	<10.0
STDEV		0.02	0.29	6.23	6.17	0.03	1.20	8.62	2.17	15.15	3.56	22.60	5.26
AVERAGE	1990	0.02	0.23	8.06	8.29	0.02	<1.00	10.09	4.13	1.52	6.92	4.66	11.82
MAXIMUM		0.10	1.40	21.70	21.80	0.04	2.50	21.00	15.20	4.83	212.00	15.00	26.00
MEDIAN		<0.02	<0.20	7.38	7.71	0.02	<1.00	9.92	3.60	1.34	1.20	4.00	11.00
MINIMUM		<0.02	<0.20	4.11	4.21	0.01	<1.00	5.85	2.22	0.03	0.71	3.00	<10.0
STDEV		0.02	0.24	3.32	3.33	0.01	0.59	2.89	2.35	0.92	34.17	2.21	6.79

TABLE 29. Summary of chemical analyses from the Enterline field drain (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	1991	0.03	0.20	6.21	6.41	0.02	<1.00	8.98	3.10	1.34	1.16	3.83	14.17
MAXIMUM		0.05	0.54	8.23	8.45	0.06	4.20	10.90	3.52	1.80	2.52	4.00	25.00
MEDIAN		0.02	<0.20	6.29	6.39	0.02	<1.00	9.06	3.08	1.32	0.95	4.00	11.00
MINIMUM		<0.02	<0.20	4.84	5.10	0.01	<1.00	7.30	2.59	1.01	0.59	3.00	<10.0
STDEV		0.02	0.13	0.89	0.93	0.01	0.93	0.99	0.26	0.15	0.52	0.38	6.82
AVERAGE	1992	0.02	<0.20	4.81	4.96	0.02	1.03	7.14	2.93	1.11	1.15	3.17	15.28
MAXIMUM		0.03	0.40	6.53	6.63	0.04	4.00	9.50	3.68	1.32	1.95	5.00	33.00
MEDIAN		0.02	<0.20	4.60	4.75	0.02	<1.00	7.03	2.80	1.11	1.03	3.00	17.00
MINIMUM		<0.02	<0.20	2.07	2.31	0.01	<1.00	5.26	2.09	0.75	0.75	2.00	<10.0
STDEV		0.01	0.08	1.50	1.47	0.01	1.00	1.19	0.54	0.13	0.32	0.92	8.88

TABLE 30. Summary of chemical analyses from the Enterline surface runoff

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	PERIOD	0.21	0.69	7.40	8.08	0.12	6.09	11.63	4.38	2.48	2.91	5.25	13.23
MAXIMUM	OF	5.94	6.27	39.90	46.17	3.74	38.60	61.90	14.30	71.40	18.70	106.00	31.00
MEDIAN	RECORD	0.05	0.56	6.72	7.12	0.06	4.10	10.45	4.42	1.25	1.97	4.00	13.00
MINIMUM		<0.02	<0.20	<0.04	0.51	0.01	<1.00	3.34	1.31	0.10	0.49	1.00	<10.0
STDEV		0.78	0.80	7.30	7.74	0.33	6.13	9.53	2.35	9.07	2.58	10.63	7.16
AVERAGE	1987	0.09	0.69	6.90	7.60	0.07	5.05	9.38	4.48	1.51	2.99	5.33	20.42
MAXIMUM		0.42	1.54	12.32	13.78	0.22	11.80	12.10	5.31	2.00	10.00	12.00	31.00
MEDIAN		0.04	0.50	6.93	7.59	0.06	5.15	10.20	4.60	1.71	2.30	5.00	20.50
MINIMUM		<0.02	<0.20	2.20	2.80	0.01	<1.00	5.57	3.12	0.89	1.24	4.00	<10.0
STDEV		0.12	0.50	3.15	3.12	0.06	4.01	1.89	0.71	0.38	2.41	2.23	6.54
AVERAGE	1988	0.52	0.72	10.16	10.88	0.21	4.46	15.48	4.98	1.35	3.54	4.70	16.26
MAXIMUM		5.94	6.27	39.90	46.17	3.74	38.60	61.90	14.30	2.92	18.70	11.00	31.00
MEDIAN		0.08	0.22	7.04	7.55	0.07	3.10	10.70	4.18	1.31	1.97	4.00	17.00
MINIMUM		<0.02	<0.20	0.06	0.88	0.03	<1.00	4.90	1.31	0.27	0.49	1.00	<10.0
STDEV		1.31	1.31	10.64	11.62	0.55	5.80	15.09	3.39	0.58	3.62	2.43	6.87
AVERAGE	1989	0.03	0.51	5.47	5.99	0.10	9.01	8.78	3.81	6.14	3.61	8.71	8.74
MAXIMUM		0.38	1.30	14.30	14.84	0.60	35.00	14.70	7.36	71.40	8.78	106.00	22.00
MEDIAN		<0.02	0.49	5.15	5.49	0.06	4.10	10.30	4.45	1.30	3.45	4.00	<10.0
MINIMUM		<0.02	<0.20	<0.04	0.51	0.01	<1.00	3.34	1.31	0.10	1.10	2.00	<10.0
STDEV		0.06	0.26	5.57	5.43	0.11	8.64	4.25	2.09	17.81	2.03	21.13	4.93

TABLE 30. Summary of chemical analyses from the Enterline surface runoff (Continued)

	DATE	NH3-N	TKN	NO23-N	TN	TP	TOC	CA	MG	NA	K	CL	SO4
AVERAGE	1990	0.07	0.81	6.19	7.01	0.07	6.04	10.60	4.20	1.10	1.69	3.27	11.11
MAXIMUM		0.28	1.60	13.30	13.85	0.27	16.00	18.00	5.89	1.94	3.95	6.00	24.00
MEDIAN		0.07	0.82	6.65	7.42	0.05	5.00	10.85	4.59	1.16	1.44	3.00	10.50
MINIMUM		<0.02	<0.20	0.22	1.20	0.02	1.90	4.09	1.47	0.19	1.00	2.00	<10.0
STDEV		0.05	0.30	3.52	3.32	0.05	3.50	3.01	1.14	0.50	0.65	1.09	5.94
	1991	One sample collected on 1/17/91											
		0.05	0.20	6.78	6.98	0.04	2.10	9.46	4.45	1.16	1.21	3.00	14.00
AVERAGE	1992	0.03	0.49	5.81	6.29	0.04	2.60	7.54	3.74	1.12	2.83	3.50	24.00
MAXIMUM		0.04	0.56	6.53	6.94	0.06	2.70	7.81	4.02	1.14	3.69	4.00	25.00
MEDIAN		0.03	0.49	5.81	6.29	0.04	2.60	7.54	3.74	1.12	2.83	3.50	24.00
MINIMUM		<0.02	0.41	5.08	5.64	0.02	2.50	7.26	3.46	1.10	1.97	3.00	23.00
STDEV		0.02	0.11	1.03	0.92	0.03	0.14	0.39	0.40	0.03	1.22	0.71	1.41

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